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Iodized Salt and Iodized Water in the Control of Iodine Deficiency Disorders (IDD) in Thailand

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Abstract : The use of drinking water as an additional vehicle for iodine to common salt has its origin in the fact that a low and irregular intake of common salt has led to a high prevalence of goitre in the north of Thailand. The distribution of salt in the north is poor. Culturally water is offered to passers-by and guests in every house. Thus, iodized salt and iodized water are combined to increase the effectiveness of both for children in primary schools in a village in Nan province where goitre is prevalent. At the end of 12 months of a strictly controlled study in 172 placebo and 114 treated subjects, the prevalence in the treated group was reduced dramatically from 60.2% to 10.5%. The urine and serum findings in the post-test samples became normal when compared with those of the pre-test samples. Both iodized salt and iodized water have been used to help relieve iodine deficiency to date. No complications were found in this series of volunteers. Monitoring and evaluation of the method show that, if the daily dose of iodized salt is consistently 50 ppm and that of iodized water 100 µg per litre, this can be continued indefinitely until all areas of the country are fully developed. In conclusion, using combined iodized products under close supervision is definitely more effective than using iodized salt or iodized water alone.

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เรื่องย่อ : **เกลือและน้ำผสมไอโอดีนในการควบคุมโรคขาดสารไอโอดีนในประเทศไทย**

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น้ำดื่มนับเป็นพาหะในการเสริมไอโอดีนที่สำคัญอีกอย่างหนึ่งนอกเหนือจากเกลือผสมไอโอดีน ทั้งนี้เนื่องจากคนในภาคเหนือของประเทศไทยบริโภคเกลือน้อยและไม่สม่ำเสมอเท่าที่ควร และภาคเหนือเป็นภาคที่มีเกลือไม่แพร่หลาย ประกอบกับวัฒนธรรมของคนในภาคเหนือจะจัดน้ำดื่มไว้ให้แก่คนที่ผ่านไปมาและแขกที่มาเยือน จึงได้ศึกษาประสิทธิผลของการบริโภคเกลือร่วมกับน้ำผสมไอโอดีนในเด็กชั้นประถมศึกษาของหมู่บ้านคอพอกในจังหวัดน่าน โดยแบ่งเป็นกลุ่มที่ไม่ได้รับไอโอดีน 172 คน และกลุ่มที่ได้รับไอโอดีน 114 คน เมื่อครบ 12 เดือน พบว่าความชุกของโรคขาดสารไอโอดีนในกลุ่มที่ได้รับไอโอดีนลดลงอย่างมาก คือจากร้อยละ 60.2 เหลือร้อยละ 10.5 ผลการตรวจปัสสาวะและซีรั่มที่เคยพบว่าผิดปกติก็กลับคืนสู่ปกติ

จากผลการศึกษาดังกล่าวผู้วิจัยจึงได้ใช้น้ำและเกลือผสมไอโอดีนในการควบคุมโรคขาดสารไอโอดีนมาจนกระทั่งทุกวันนี้โดยไม่พบว่ามีภาวะแทรกซ้อน การตรวจและประเมินวิธีการนี้แสดงว่าขนาดของเกลือผสมไอโอดีนต่อวันที่ควรได้เป็น 50 ส่วนในล้านส่วน และของน้ำผสมไอโอดีนเป็น 100 ไมโครกรัมต่อลิตร และให้ติดต่อกันได้ตลอดไปจนกระทั่งจังหวัดใกล้ชายแดนดังกล่าวจะมีความเจริญเต็มที่

โดยสรุปผลของการให้ไอโอดีนดดยอาศัยพาหะทั้งสองอย่างร่วมกันภายใต้การดูแลอย่างใกล้ชิดได้ผลดีกว่าการให้เพียงอย่างใดอย่างหนึ่ง

INTRODUCTION

Following the great concern of HM King Bhumipol and HRH Princess Phra Debharatana which has motivated in recent interest and support, the prevalence of goiter has been reduced from 84.4% in 1953[1] to 4.9, 3.2, 2.8% as of 1997-1999 so that it is no longer a public health problem. However, elimination has to be continued otherwise recurrence will occur as in the past[2]. It must be kept in mind that consistent effort towards reaching total elimination of deficiency goitre prevents mental retardation and eventually brain deterioration in the next generation.

In the control of iodine deficiency disorders (IDD), the two iodized vehicles, salt, used first by Marine and Kimball since 1917[3] and more recently drinking water[4], have been used to carry iodine adequate for body requirement. A combination of iodized salt and water corrects the iodine deficiency and brain complications within a shorter period of time than either iodised vehicle alone.

It is well known that common salt is a good vehicle of iodine for controlling IDD[5]. Iodized water was introduced and proved to be effective and gained more attention. The storage and use of water are by jars of water with KIO_3 added for houses or by

iodinators supplying iodized water to feed school children and villagers[6]. This method was initiated in Nan and Mae Hong Sorn province. A box of KIO_3 was placed within a plastic barrel along with some diverted piped water and the mixed water was then re-introduced into the main stream[7]. Polymers containing KIO_3 were introduced into a well. The compound diffused slowly into the water over a period lasting up to one year[8]. Iodization of irrigation water, which has the additional advantage of simultaneously correcting iodine deficiency in plants and animals, has been undertaken in China and studied in Thailand[9]. Culturally, Thais habitually provide drinking water for passers-by and guests in every house in the northern part of the country. Iodized water was then considered as a convenient vehicle for introducing iodine in addition to common salt.

The area of Northern Thailand is mountainous, and, during the rainy season, the rainfall has repeatedly leached down the ground surface soil that is rich in iodine. Moreover, people in the North, even the priests, ingest much less common salt (e.g. < 3-5 grams of common salt/person/day) than those in other regions, resulting in an inadequate intake of salt. Besides, the iodized salt has been poorly distributed up to the present time[10]. In Bangkok and other provinces with a rich supply of iodine, 10 grams of common salt are routinely consumed daily except for old people with edema from congestive heart failure who use potassium chloride as a substitute for sodium chloride which does not help since its taste is too caustic[11]. Thus, when only iodized salt was ingested, the regression of the goitre was delayed. Therefore, another kind of vehicle in addition to common salt was needed to carry enough iodine to meet the body requirement. Then, double iodized vehicles *(iodized salt and iodized water, and not iodized salt or iodized water),* not iodized salt alone, however much the quantity ingested increased, ensure a good supply of iodine.

Therefore, a combination of both iodized salt and iodized water was given to the iodine-deficient subjects of the villages in the north of Thailand with goitre endemic for a full year. The objective is to give the same amount of iodine in the mixture of iodized salt and iodized water ingested daily compared with the amount given either as iodized salt *or* iodized water alone.

MATERIALS AND METHODS

The 114 placebo cases and 172 treatment cases were randomly selected from school children, 6-12 years of age, from the villages Nam Liang and Fuey Loong, in the mountainous parts of the Toong Chang district in Nan province. The areas are adjacent to the Democratic People's Republic of Laos. Subjects in the treated group took *iodized salt* daily at a concentration of 1:20,000 or 50 ppm (Figure 1), in combination with iodized water at 100 µg per 1,000 ml. A salt-mixing unit could produce iodized salt *en masse*. The iodized water was produced by an *iodinator* (Figure 2), a dosing device of KIO_3 solution, being attached to pipes of water distributed from a reservoir of mountain water to every school and house.

The baseline and treated data for prevalence, grading, urine iodine and serum findings of both groups, the placebo and the treated ones, were obtained for pre- and post-tests, respectively.

The size of the goitre was classified according to the WHO classification[11]; analysis of urine iodine by Dunn's method[12], assay of serum T3, T4 and TSH by RIAs and IRMA[13-15], and antibodies for microsomes and thyroglobulins by Thymune M and Thymune T (Burrough Wellcome)[16] were carried out.

RESULTS

Prevalence

The reduction in the prevalence of goitre and the improvements in the grade of goitre are shown in Table I and Figure 3. The results at the end of 12 months were remarkable; the prevalence in the treated group was reduced from 60.2% to 10.5% with almost complete disappearance of grade Ib and grade 2. The placebo group was given ordinary salt alone. The pre-test and post-test ratio of placebo was 1.3 which showed definitely less than those of treated group of 5.7, confirming obviously good results after treatment by iodized salt and iodized water.

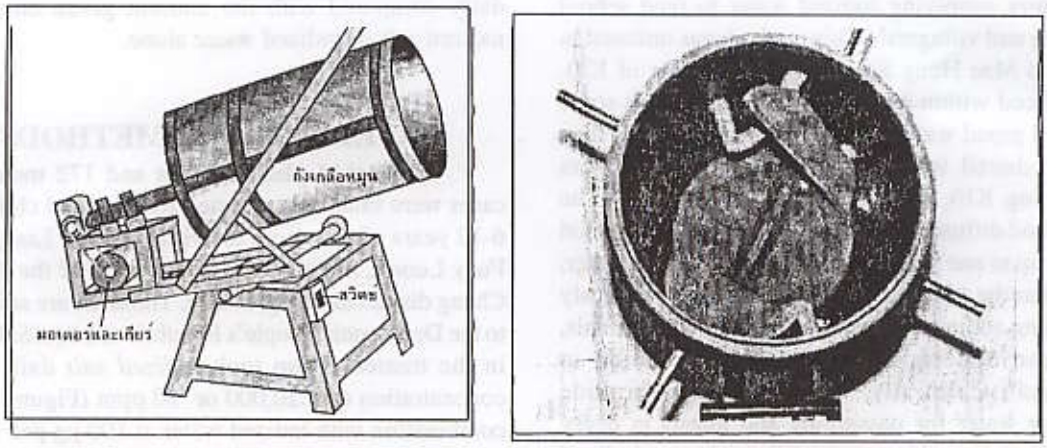

Figure 1. (A) Showed the mixing unit of salt and iodine, and a half horsepower motor.
(B) A rotating barrel of the mixing unit contains two blades of polyethylene for turning and mixing the salt evenly. It declines about 15 degrees on the iron base.

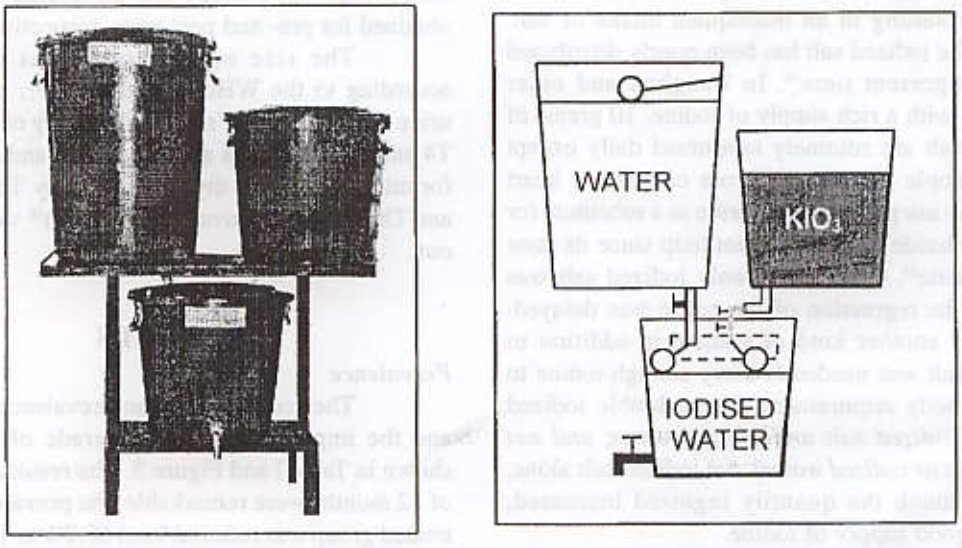

Figure 2. An iodinator, or a barrel for mixing KIO_3 with raw water, produces a large amount of iodized water, enough to feed the population of the whole village and school.

Table 1. Prevalence and grading of goitre in the control of IDD by a combination of iodized salt and iodized water at 12 months in placebo and treated groups.

	Goitre rate		Grade (%)		
	n/N*	%	1a	1b	2
Pre-test					
Placebo	81/108	75.0	49.1	25.0	0.9
Treated	97/161	60.2	54.0	6.2	0
Post-test					
Placebo	66/114	57.9	39.5	11.4	7.0
Treated	18/172	10.5	9.3	1.2	0

*n = number of children with goitre, N = total number of cases

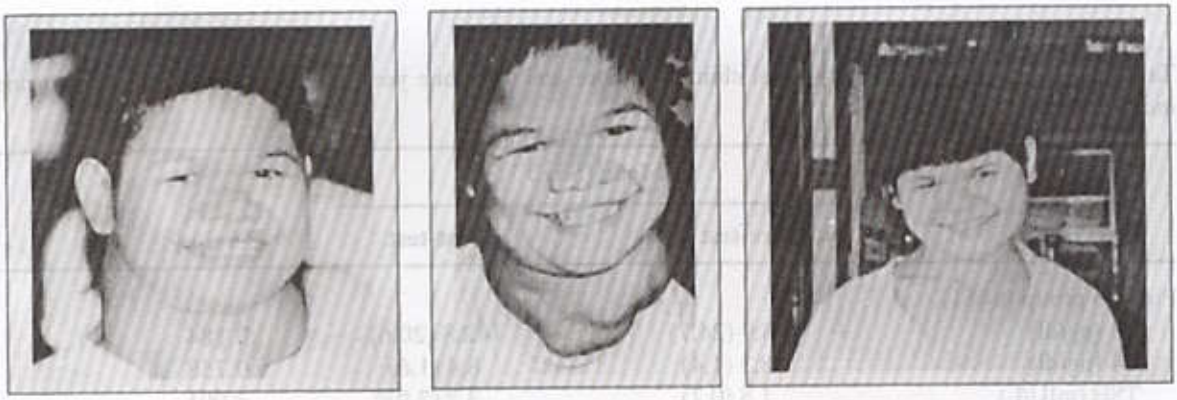

Figure 3. A series of photographs of a girl showing a large multi-nodular goitre. After taking *iodized salt and iodized water daily* for 4 years, the goitre disappeared.

Urine iodine

Pre-test urinary iodine excretion in the placebo and treated groups was found to be consistently below 100 µg per day. At 6 months the daily urine iodine excretion was about 276 µg, and at 12 months, 155 µg in the treated group (Table 2).

Table 2. Urine iodine excretion in the school children before and after administration of *iodized salt and iodized water.*

	Urine iodine excretion (µg/g creatinine)			
	Placebo group		Treated group	
	N	Mean (S.D.)	N	Mean (S.D.)
Pre-test	92	82.7 (37.4)	72	97.5 (42.2)
Post-test				
6 mth.	30	96.7 (42.6)	23	276.1 (122.6)
12 mth.	50	49.6 (28.6)	50	155.3 (63.3)

Serum findings

After 12 months, serum T4 was raised from 8.2 to 9.5 µg/dl ($p < 0.001$) and TSH from 3.2 to 2.6 mIU/L ($p = 0.028$). T3 was reduced from 141.9 to 134.6 ng/dl ($p = 0.1$). Thymune M and Thymune T were negative. The tendency was towards reversion to normal. (Table 3)

Table 3. Serum findings in the school children before and after one year treatment using *iodized salt and iodized water.*

	Mean (S.D.)		
	Pre-test	Post-test	P value
Placebo group (n=51)			
T3 (ng/dl)	148.9 (24.7)	142.8 (20.6)	0.184
T4 (µg/dl)	8.3 (1.4)	8.4 (1.6)	0.758
TSH (mIU/L)	1.8 (0.7)	3.2 (2.9)*	<.001
Treated group (n=50)			
T3 (ng/dl)	141.9 (26.2)	134.6 (167.9)	0.105
T4 (µg/dl)	8.2 (1.6)	9.5 (1.8)	<0.0001
TSH (mIU/L)	2.1 (0.9)	2.6 (1.2)	0.028

*Six children were hypothyroid after receiving only placebo for one year.

DISCUSSION

In this well-controlled study of goitre, there were no problems in the logistics of administering the combination of iodized salt and iodized water. Potassium iodate has been supplied regularly for the iodization of common salt for many years. Communication and implementation were well conducted with excellent co-operation from the headmasters and teachers of the schools as well as the school children and their parents or guardians.

More efficient distribution of iodized salt, or the universal salt iodine (USI), where salt is iodized at the site of production, requires the co-operation of the salt producers and good communication and management. Otherwise it is necessary to use iodized water in addition to increase its efficiency.

Rationale of combining iodized water with iodized salt

In the northern provinces of Thailand, water for drinking is customarily stored in very small single or twin earthen pots in every kitchen or the front of each house of all villages. In almost every school, there are medium sized coolers as well as larger jars as reservoirs, containing about 200 litres of iodized water. Moreover, from the iodinators (Figure 4), the iodized water is produced.

Figure 4 shows iodine cycle made complete from the beginning of iodine in the rain which is absorbed in the surface soil on the mountain to end up in that of the ground of the field below. In between, large amount of mountainous water is drawn up into the elevated tank and passes down through a large iodinator. Hence, parts of the iodized water are distributed to the pond for fowls and fish, and to the ground for agriculture and husbandry as well as to feed the human beings, i.e. schools and its villages. The pond is surrounded by vertiver grass of which iodized water is held. All the ground and living organism are enabled to have benefits from presence of fresh elemental iodine. The area and its products generally poor in iodine are thus iodized naturally probably reducing the need for any additional supplementation.

Returning to the raw water that artificially represents the inflow water to the iodinator, the amount of iodine as potassium iodate solution is pre-determined and put into the drinking water by villagers or the teachers, or mothers. However, the daily intake of water has a wider range than that of common salt. On average, it is almost one to two litres of water per person per day depending on their physical activity. If the children do not receive iodine on any day for any reason, they may have, on the average, iodine within the wide margin of the total intake for 1,000 ml of water or 100 µg of iodine, which is still within normal limits.

Monitoring *on site* with an instant kit[17] for the immediate detection of iodine in both iodized salt and iodized water respectively, is a very practical and convenient way of evaluating IDD. In this way, intake is satisfactorily monitored by monitoring urine. Villagers could become self-sufficient in their ability to monitor levels of iodine in drinking water and levels in urine.

The dose of iodine in one gram/bottle of 30 ml is prepared from a dilution of a medicinal bottle of 300 ml with 10 grams of potassium iodate, which is divided into ten 30 ml bottles (Figure 5). The preparation of twin bottles for detection of iodine in water and those of single bottle for salt respectively, are published elsewhere[19]. Both single and double bottles technique are important for monitoring and evaluation of IDD control.

Comparing the results using combined iodised salt and iodized water with those using a single vehicle (iodized salt or iodized water) in the same area (county) of Nan province, it can be seen that the effects of combined iodized salt plus iodized water on goitre are superior to iodised salt or iodised water alone. As an example, Table 4 was provided for the demonstration. By using iodized salt (non-supervised), an appreciable reduction in goitre prevalence was obtained within three years (1962-1964), while by using iodized water alone a reduction was obtained within two years (1986-1987). In contrast, iodized salt and iodized water (1989) which was carefully supervised, took only one year to reduce the prevalence of goitre to far below its usual prevalence.

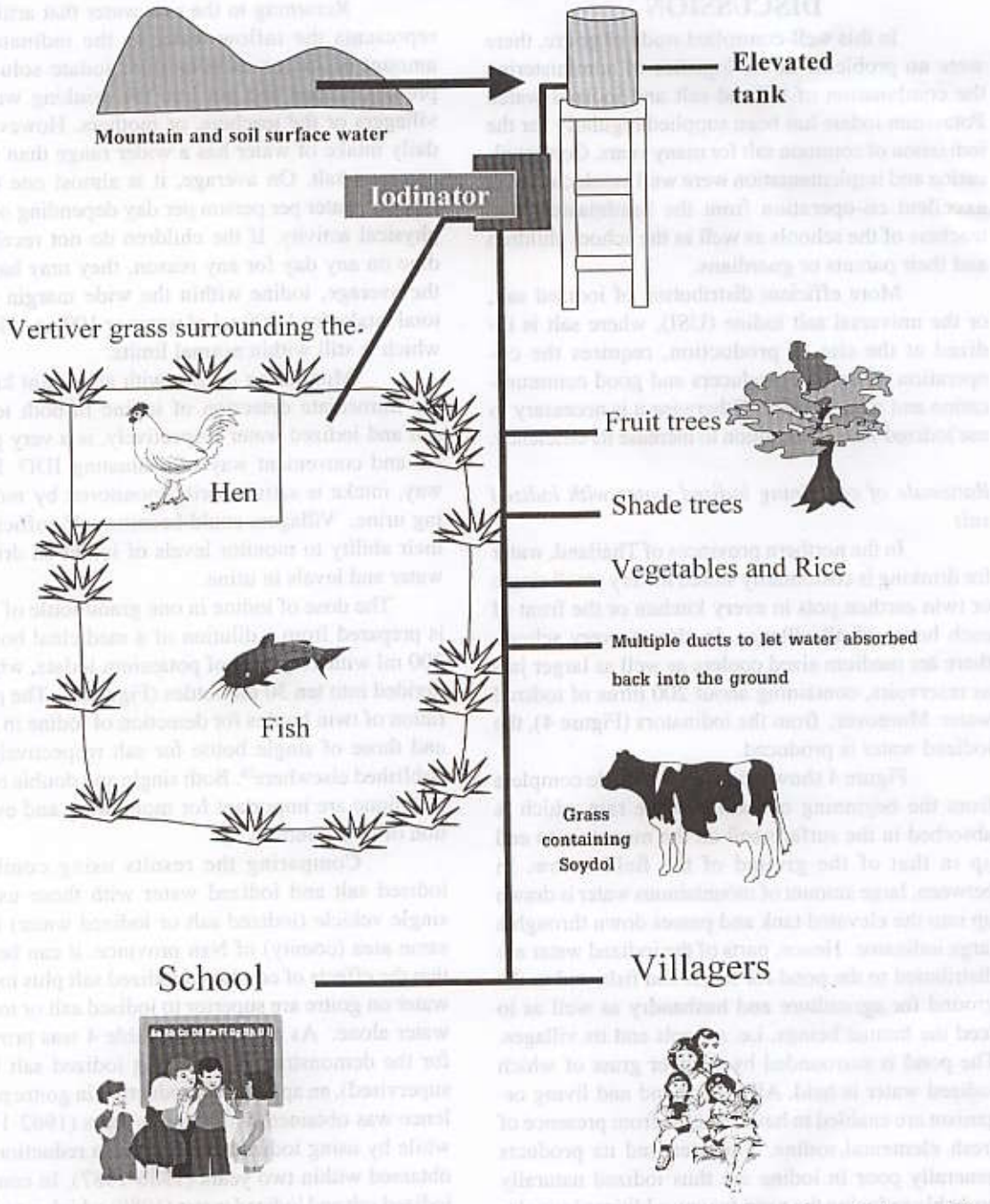

Figure 4. Showing mountainous water accumulated in an elevated tank and iodized by a large iodinator. The iodized water is made uses to human beings and also different living animals including plants, fruit and shady trees of the village, and school areas. The water is then injected back into the ground completing the iodine cycle.

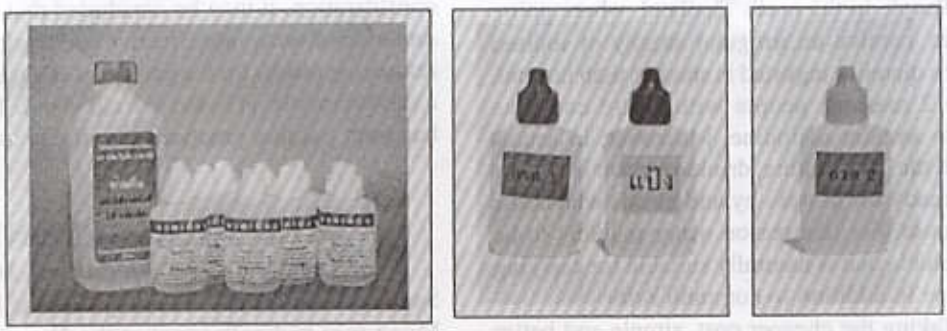

Figure 5. (A) A medicinal bottle of KIO_3, divided into ten bottles. (A') Single bottle of KIO_3. (B) Twin bottles of iodine detector for salt and water. Note the separated bottle for acidification. (C) Single bottle for detection of iodized salt.

Table 4. Comparison of the reduction in the rate of goitre using a single or a combined vehicle in villages in Nan province.

	Duration (months)	Rate of goitre (%)	Reduction down to (%)	Difference (%)
Salt alone	**36**	**84.4**	**42.4**	42.0
Water alone	**24**	**74.4**	**40.9**	33.5
Iodized oil	24	95.3	42.9	52.4
Salt & water	**12**	**60.2**	**10.5**	49.7
Placebo	12	82.2	78.0	4.2

Dosage of iodine

When administering the combined vehicles, the daily dosage of iodine for patients with goitre should be within the region of 200 micrograms[18]. In other words, a daily intake of 200 micrograms of iodine can suppress the increased TSH level down to a nearly normal value. This amount of iodine appears to be the optimal concentration for daily supplementation of iodine. One hundred micrograms of iodine of each vehicle are 100 x 1.685 or about 175 µg of potassium iodate. To receive iodine from both iodized salt and iodized water, 200 µg of iodine or 350 µg of potassium iodate daily is adequate.

It is well known that iodized salt is the mainstay of the progress for the control of IDD. Water, the great solvent, is more critical for life than common salt. A large quantity of water has to be consumed by every body every day. Thus iodine as liberated from iodized salt and iodized water can be regularly, and continually obtained by the whole population. No evidence of complications (Jod-basedow or Hashimoto's disease) was observed. Thus, the iodine in water should be considered complementary to that in common salt.

CONCLUSION

People in the north Thailand, where goitre is endemic, receive an irregular supply of iodised salt and the quantity ingested is smaller than normal. For these 2 reasons, people with goitre consume inadequate amount of iodine. Moreover, in accordance with the Thai culture, drinking water is always prepared ready for passers-by and guests who come to each house. For this reason *water is* likely to be another vehicle that is naturally suitable for carrying more iodine in addition to common *salt.*

Taking the cheaper cost, simple and better effectiveness of combined iodized salt and iodized water with the ease of their administration into consideration, it may be concluded that *iodized salt and iodized water* are effective and workable, giving reassuring results for the control of IDD, and reaching a satisfactory level in the thyroid gland. This method has been put into practice up to the present time.

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