The Bacterial Quality of Lake Waters at Yellowknife, Northwest Territories

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ABSTRACT. A study was conducted to measure the degree of contamination of lake waters at Yellowknife produced by the disposal of domestic wastes, and to assess the suitability of these waters for domestic use. None of the samples analysed met Canadian standards for drinking water. Though the bacterial quality of the main body of water was found to be good, there was contamination at points of discharge of sewage and near storm drains, marsh muds and sediments. It is recommended that the City of Yellowknife seek an alternative site for sewage disposal and give adequate publicity to the dangers of using inadequately treated water.

RÉSUMÉ. *La qualité bactérienne des eaux lacustres à Yellowknife, Territoires du Nord-Ouest.* Une étude a été menée afin de mesurer le degré de contamination des eaux lacustres de Yellowknife produite par l'écoulement des déchets domestiques et d'évaluer la salubrité de ces eaux destinées à l'usage domestique. Aucun des prélèvements analysés ne se conformait aux standards canadiens régissant l'eau potable. Bien que la qualité bactérienne de l'ensemble des eaux ait été bonne, on trouva de la contamination aux points de déversement des égouts dans les lacs, près des bouches d'égouts, dans la boue et sédiments marécageux. On a recommandé à la ville de Yellowknife de trouver un autre endroit pour le déchargement des égouts et de faire une publicité suffisante pour mettre le public en garde contre les dangers d'utiliser des eaux inadéquatement traitées.

РЕЗЮМЕ. *Содержание бактерий в озерной воде в районе г. Йеллоунайфа, Северо-Западные территории.* Изучалась степень загрязнения озерной воды городскимн отходами в районе Йеллоунайфа, и проводилась оценка пригодности этой воды для бытового потребления. Ни одна из проанализированных проб не отвечала канадским стандартам для питьевой воды. Хотя содержание бактерий в основной массе воды было найдено удовлетворительным, значительный уровень загрязнения имел место в местах сброса сточных вод, вблизи ливневых колекторов, а также в болотной грязи и наносах. Была подана рекомендация, в которой предлагалось, чтобы администрация г. Йеллоунайф рассмотрела новые места для сброса сточных вод, а также информировала население о возможных последствиях использования недостаточно очищенной воды.

INTRODUCTION

Yellowknife is the largest city in the Northwest Territories of Canada. Its present population of 9,800 will, according to current predictions, increase to 16,300 by 1990 (Pick 1975). The disposal of its domestic waste has been achieved by lagooning in a small lake (Niven Lake) with subsequent discharge to Back Bay which forms an area of Yellowknife Bay on the northern shores of Great Slave Lake (approximately 114°25′W, 62°26′N). Grainge (1971) suggested that Niven Lake was providing poor treatment and that an alternative means of sewage disposal should be sought. He noted in the same report that the effluent was not

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disinfected and that the receiving water was unsuitable for drinking.

Public health problems are not a novelty in the North although identification of waterborne routes of infection is often difficult. McCabe and Craun (1975) reported 112 cases of gastroenteritis among persons consuming water at a roadside restaurant on the Alaska Highway between Tok Junction and Whitehorse. Yamamoto (1975) has made reference to outbreaks of infectious hepatitis in the Canadian North, including a 1973 outbreak of 288 cases in the Baffin region (thirteen communities with a total population of 7,000, lying between Arctic Bay and Frobisher Bay). Yamamoto (1975) also demonstrated the presence of a large number of viruses (110 plaque-forming units per litre) in the sewage effluent from Niven Lake.

The dissemination of large numbers of bacteria, particularly bacterial pathogens, relating as it does to the associated problems of water supply and sewage disposal, is perhaps of more concern in the North than elsewhere, for these organisms survive longer at low temperatures. *Salmonella*, a bacterial pathogen, has been shown to survive at least seven days in the Tanana River (Van Donsel *et al.* 1974), and the organisms associated with the presence of bacterial pathogens, coliforms, faecal coliforms and faecal streptococci, have been shown to have similar survival rates in the same river (Gordon 1972.) The water temperature of the Tanana River was 0°C at the time of the two studies.

Many small settlements in the North do not have a central water supply or waste disposal system. Even in larger communities such as Yellowknife, only part of the town is on such a system. Heinke and Deans (1973) have shown that a great deal of the water of Frobisher Bay, N.W.T. (64°N, 63°30'W) is supplied by truck, and its sewage disposal is accomplished by "honey bags" or by storage in a holding tank with subsequent trucking to a central location. This is analogous to the situation in "Old Town," a section of Yellowknife largely inhabited by native people, transients and squatters. While most of the inhabitants of "Old Town" are supplied with trucked or piped water during summer, there are a number of dwelling places along the shores of Back Bay and Yellowknife Bay and locations on nearby islands where the only fresh water comes from these bays, into which an unsterilized sewage effluent is directly discharged.

In the light of these facts, a study was undertaken by Environment Canada to assess the effects, and define the zone of influence, of the Niven Lake discharge; to assess the bacterial quality of those waters likely used as a domestic supply by local inhabitants; to define other point sources of bacterial pollution and, on the basis of the findings, to make recommendations to the water authorities of the City of Yellowknife and the North West Territories.

METHOD OF STUDY

Water samples were collected from a depth of one metre at each of the water quality monitor stations shown on Fig. 1. The samples were taken eight times during the period 2 September to 7 October 1975. The sewage effluent zone was sampled three times under varying weather conditions, and the potable water stations were sampled once. The point-source stations (Fig. 2) were sampled once

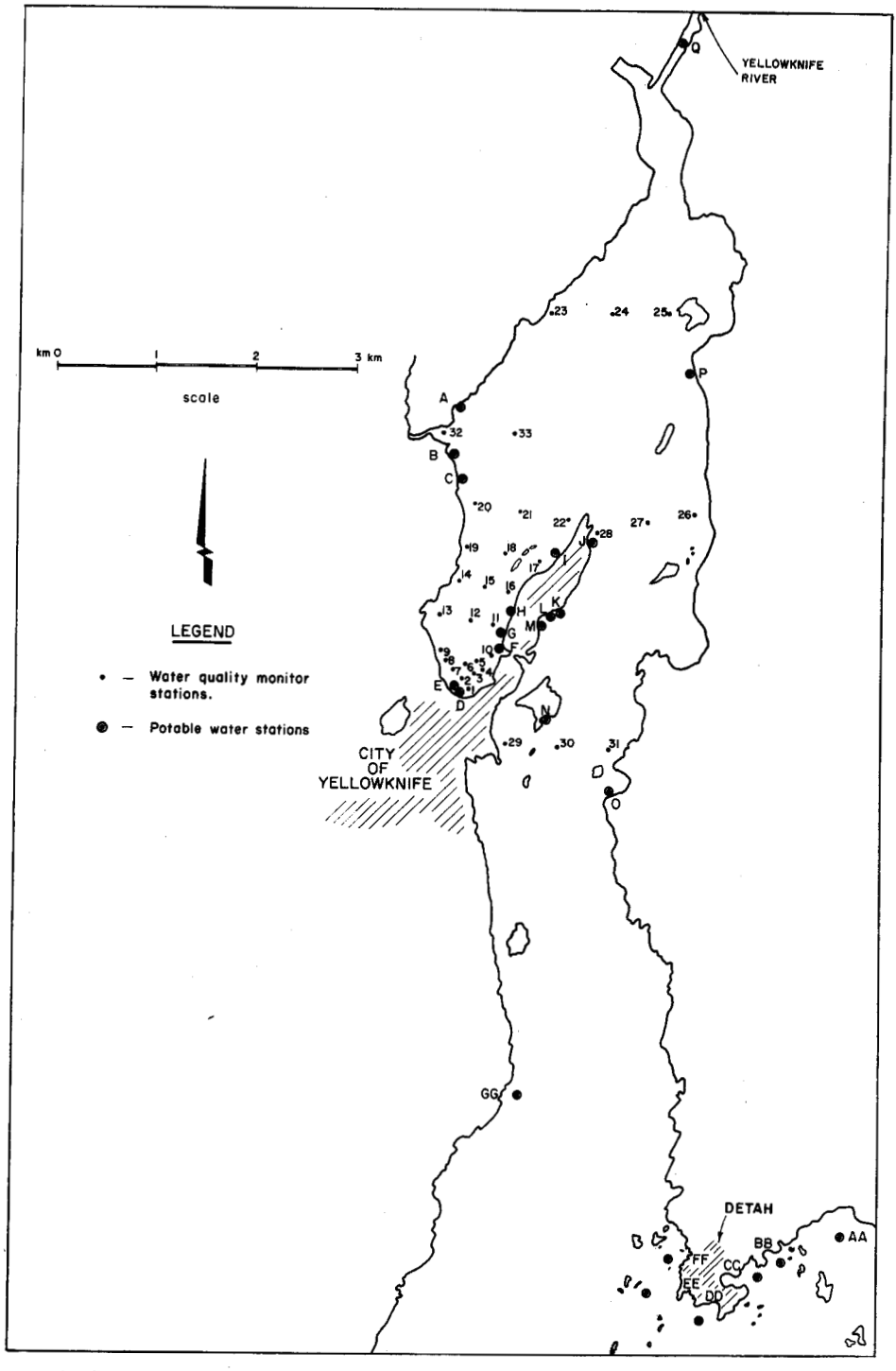

FIG. 1 Sampling locations, Back Bay and Yellowknife Bay.

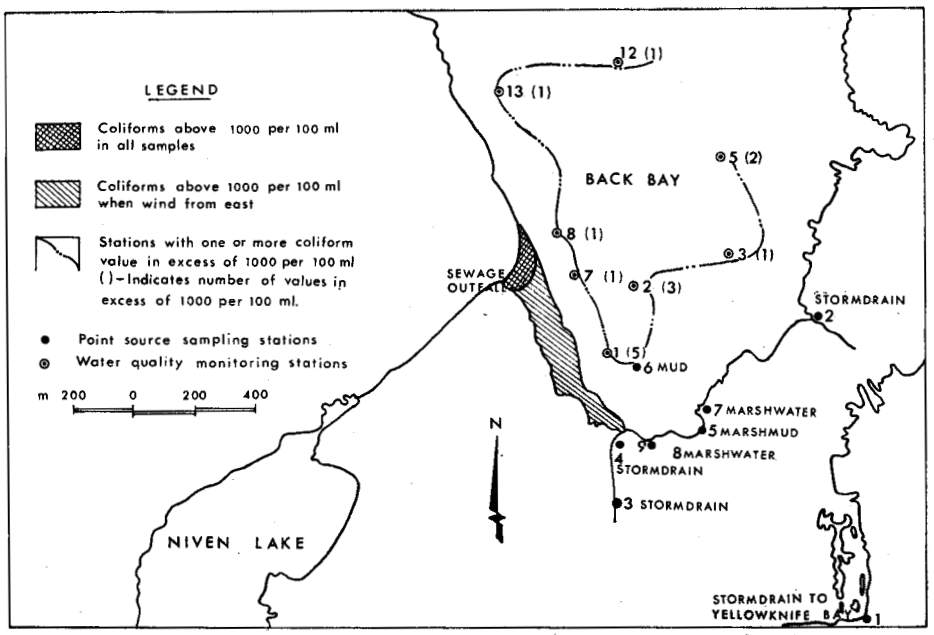

FIG. 2 Zone of influence of sewage outfall at Back Bay and of other point source sampling stations.

during a period of rainfall. Samples of sewage influent and effluent were collected eight times during the study period.

Bacterial analyses for total coliform, faecal coliform, faecal streptococci, standard plate counts (S.P.C.) at 20° C and 35° C, and spread plate counts at 20° C were conducted in a field laboratory, usually within two to eight hours of the time the samples were collected. All samples were subjected to standard membrane filtration procedures (A.P.H.A. 1971) for total coliforms, faecal coliforms and faecal streptococci, the medium of choice being LES Endo Agar, M-FC Agar and M-Enterococcus Agar respectively. Standard plate counts were performed according to the pour-plate method (A.P.H.A. 1971) with incubation periods of 24 ± 2 hours and 48 ± 2 hours for the 35° C and 20° counts respectively. Spread plate counts at 20° C were determined by the medium and method, as previously described by Bell and Jurkovic (1975) with an incubation period of 7 days. All methods have been described in detail by Bell (1975).

RESULTS AND DISCUSSION

In general, the bacterial quality of Back Bay and Yellowknife Bay can be considered good, although disinfection would be required before their water could be used for domestic consumption. The geometric mean coliform values for three sectors were respectively 360, 130 and 30 per 100 millilitres (ml) (see Table 1). These values are comparable to those reported by Bell and Vanderpost (1973) for Lake Ontario in areas where Lake Ontario was considered unpolluted. Although the values are low for the indicator organisms, the presence of bacterial

TABLE 1. Analysis of samples from water quality monitor stations

Station	Total coliform per 100 ml	Faecal coliform per 100 ml	Faecal streptococci per 100 ml	F.C./F.S.	Standard plate counts per ml 35°C	Standard plate counts per ml 20°C	Spread plate counts per ml 20°C
Sector 1							
1	780	16	3	4.00	48	190	5,300
2	390	12	2	5.89	45	110	6,600
3	260	12	2	6.47	69	170	4,300
4	260	10	2	5.36	41	86	3,200
5	330	10	4	3.85	41	120	5,500
6	250	7	2	4.87	34	100	6,500
7	390	15	2	7.00	67	120	7,200
8	490	16	4	3.99	80	230	7,100
9	500	23	3	9.10	90	240	8,300
10	150	16	3	5.00	71	130	5,400
Geom. means	360	13	3	5.61	59	140	5,900
Sector 2							
11	220	12	2	5.33	68	140	3,900
12	380	15	2	7.05	60	210	4,800
13	470	32	3	9.04	140	410	9,400
14	220	10	2	7.29	55	120	4,800
15	230	7	2	4.94	67	150	3,200
16	160	6	1	4.46	29	95	6,000
17	70	2	1	1.14	28	68	1,400
18	85	1	1	—	17	48	2,900
19	95	4	1	5.57	33	67	1,500
20	58	3	1	3.93	18	51	1,100
21	53	2	1	—	17	52	1,400
22	63	2	1	—	25	58	890
Geom. means	130	6	1	5.17	37	97	2,700
Sector 3							
23	37	1	1	—	25	69	600
24	34	1	1	—	14	48	1,100
25	30	2	1	—	8	35	600
26	29	1	1	—	22	52	770
27	32	2	1	—	21	50	950
28	32	1	1	—	20	48	1,200
29	72	7	4	1.85	37	82	560
30	32	3	1	4.00	24	74	540
31	15	2	1	—	24	68	820
32	36	2	1	1.24	20	61	1,800
33	11	1	1	—	24	50	700
Geom. means	30	2	1	1.51	20	56	810

pathogens such as *Salmonella* is possible. Dutka and Bell (1973) demonstrated the presence of *Salmonella* in the Kingston to Brockville (seaway in mileage 185 to 136) section of the St. Lawrence River where the coliform values were less than 20 per 200 ml.

None of the water samples analysed met the Canadian standards (D.N.H.W. 1968) by coliform values, which varied from 6 per 100 ml to 47,000 per 100 ml in the Back Bay and Yellowknife Bay areas (Table 2). At Detah the values were lower, with the coliform values varying from 1 to 78 per 100 ml (Table 3). Although the coliform values of the potable water supplies are generally low,

TABLE 2. Analysis of possible potable water supply in the Back Bay and Yellowknife area

Date	Station	Total coliform per 100 ml	Faecal coliform per 100 ml	Faecal streptococci per 100 ml	F.C./F.S.	Standard plate counts per ml 35°C	Standard plate counts per ml 20°C	Spread plate counts per ml 20°C
1 Oct.	A	58	<2	<1		14	83	290
29 Sept.	B	46	2	<1		29	58	990
29 Sept.	C	6	1	<1		22	38	810
30 Sept.	D	500	16	2	8.00	100	94	6,000
4 Oct.	E	47,000	910	290	3.14	1,600	Lost	250,000
1 Oct.	F	60	40	<1		24	280	6,100
4 Oct.	G	160	42	8	5.25	50	450	11,000
4 Oct.	H	120	22	4	5.50	40	1,600	15,000
6 Oct.	I	88	<2	<2		8	75	No Data
29 Sept.	J	70	<1	<1		66	65	1,200
30 Sept.	K	46	2	<1		21	15	1,100
30 Sept.	L	28	<1	<1		8	7	2,300
1 Oct.	M	10	<2	<1		7	30	900
1 Oct.	N	16	<2	3		15	41	Lost
1 Oct.	O	15	2	1		8	37	1,100
1 Oct.	P	37	<2	4		21	50	490
1 Oct.	Q	34	<2	<1		8	40	690
6 Oct.	Q	28	<2	<2		4	87	—

TABLE 3. Analysis of possible potable water in the Detah area

Date	Station	Total coliform per 100 ml	Faecal coliform per 100 ml	Faecal streptococci per 100 ml	Standard plate counts per ml 35°C	Standard plate counts per ml 20°C	Spread plate counts per ml 20°C
3 Oct.	AA	16	2	1	0	43	530
	BB	2	1	1	22	60	560
	CC	78	3	3	14	76	—
	DD	20	2	<1	33	73	—
	EE	14	1	<1	10	41	660
	FF	12	1	<1	4	35	990
	GG	1	<1	<1	27	28	470

it must be recognized that the coliform standard provides no guarantee of absolute safety. In 1962, 45,000 cases of gastroenteritis and 38 cases of typhoid were reported in Detroit, Michigan, where the coliform values were reported to be 6.5 per 100 ml (Berger *et al.* 1963). Similarly, a large outbreak of *Salmonella typhimurium* was reported in Riverside, California, where no coliforms were observed in the drinking water (Geldreich 1972). It is evident that any person consuming raw water from the areas studied jeopardizes his own health unless he first disinfects that water.

The sewage effluent discharged into Back Bay is of poor bacterial quality, with a geometric mean faecal coliform value of 5,400 per 100 ml (Table 4). The effluent (average 3.1 x 10^6 litres per day) produces only a localized effect on Back Bay (see Fig. 2). The direction of flow appears to be a function of weather and of channelling caused by sand bars in the area of discharge. During periods of easterly winds and high wave action in the bay, the flow appears to

TABLE 4. Analysis of Yellowknife sewage

Date	Total coliform per 100 ml	Faecal coliform per 100 ml	Faecal streptococci per 100 ml	F.C./F.S.	Standard plate counts per ml 30°C	Standard plate counts per ml 20°C	Spread plate counts per ml 20°C
Raw sewage influent							
3 Sept.	5,600,000	840,000	200,000	4.20	200,000	1,900,000	5,700,000
29 Sept.	46,000,000	5,200,000	400,000	13.00	190,000	160,000	Lost
30 Sept.	23,000,000	2,400,000	550,000	4.37	1,000,000	1,200,000	3,800,000
1 Oct.	39,000,000	1,900,000	570,000	3.33	780,000	1,700,000	Lost
2 Oct.	19,000,000	8,300,000	410,000	20.24	690,000	1,300,000	860,000
3 Oct.	96,000,000	17,000,000	5,600*	—	380,000	1,500,000	4,400,000
7 Oct.	21,000,000	800,000	580,000	1.38	770,000	1,100,000	30,000,000
8 Oct.	74,000,000	840,000	150,000	5.60	770,000	970,000	14,000,000
Arith. mean	40,000,000	4,700,000	360,000	7.45	600,000	1,200,000	9,700,000
Geom. mean	30,000,000	2,600,000	220,000	5.34	510,000	1,000,000	5,600,000
Median	31,000,000	2,200,000	410,000	4.37	770,000	1,300,000	4,800,000
Final discharge of effluent in Back Bay							
3 Sept.	110,000	13,000	1,300	10.00	7,500	16,000	1,000,000
29 Sept.	340,000	9,100	2,200	4.14	6,400	12,000	600,000
30 Sept.	290,000	4,900	1,900	2.58	44,000	22,000	1,100,000
1 Oct.	210,000	7,300	1,600	4.56	9,600	57,000	Lost
2 Oct.	170,000	25,000	2,500	10.00	6,700	64,000	920,000
3 Oct.	83,000	4,500	750	6.00	11,000	74,000	900,000
4 Oct.	87,000	1,100	970	1.13	3,300	21,000	660,000
7 Oct.	170,000	3,300	1,300	2.54	9,200	23,000	1,900,000
8 Oct.	120,000	5,600	2,800	2.00	7,200	13,000	2,200,000
Arith. mean	180,000	7,600	1,800	4.12	12,000	36,000	1,200,000
Geom. mean	160,000	5,400	1,600	3.37	9,000	29,000	1,100,000
Median	170,000	5,300	1,800	3.36	8,200	23,000	920,000

*Data considered erroneous.

be to the south and likely accounts for the high coliform value of 47,000 per 100 ml at potable water station E. During calm weather the flow is to the north. The effects are only detectable within 6-15 metres of the shore and approximately 100-200 metres either side of the point of discharge. Sterilization of the effluent may lead to an overall lowering of the bacterial values in the study area, although absolute predictions cannot be made.

The bacterial values were noted to be higher in Sector 1 (see Table 1), and these elevated numbers may be due in part to the influences of the sewage effluent. Other point sources of pollution which may account for the higher numbers are storm drains flowing into the bay in the southern section, bottom muds, marsh mud and marsh waters in the southernmost part of the bay. Geldreich and Kenner (1969) have developed the concept of faecal coliform to faecal streptococci F.C./F.S. ratio as a means of determining the source of contamination. In a large sampling of non-human animal wastes they found this ratio to be consistently less that 0.7, and for human sources consistently greater than 4.0. The age of the sample and time it has been away from source are important factors in assessing these ratios, due to the differential die-away rates of faecal coliforms and faecal streptococci. Feachem (1975) has demonstrated an improved role for the use of the F.C./F.S. ratio; he concludes that if it is initially high and then falls, human contamination is indicated whereas if it is initially low and subsequently rises, a

non-human source is indicated. Even though elevated values were observed at the other point sources (Table 5), analyses of F.C./F.S. ratios indicate that the sources of bacteria were either of animal origin or non-human. The large dog population may account for this circumstance, and the ratios lead the present authors to believe that the storm sewers sampled do not possess a high domestic waste content.

TABLE 5. Analysis of samples taken during heavy rainfall at storm drains and near mud and marshes

	Total coliform per 100 ml	Faecal coliform per 100 ml	Faecal streptococci per 100 ml	F.C./F.S.	Standard plate counts per ml		Spread plate counts per ml
					35°C	20°C	20°C
1. Storm drain	87,000	17,000	24,000	0.71	9,300	67,000	1,200,000
2. Storm drain	7,100	1,600	19,000	0.08	4,500	75,000	560,000
3. Storm drain	1,400	200	2,600	0.08	1,300	22,000	590,000
4. Storm drain	1,300	300	1,800	0.17	920	9,800	480,000
5. Marsh mud	19,000	300	10	—	7,500	58,000	12,000,000
6. Mud from water quality monitoring station no. 1	18,000	10	10	—	460	4,300	170,000
7. Marsh water	700	20	100	0.20	920	6,500	1,300,000
8. Marsh water	620	90	80	1.13	220	6,000	260,000
9. Marsh water	6,200	160	80	2.00	620	12,000	660,000

CONCLUSIONS

Because of the local attitudes towards water usage in the North, where sources of it are generally considered to be of good quality and safe to drink from, the authors recognize that the most difficult task is that of educating the local inhabitants to the dangers of water consumption without proper sterilization. It is clear that, in general, the bacterial state of the waters of Back Bay and Yellowknife Bay is good, but nevertheless, not such that they can be drunk without prior treatment.

The City of Yellowknife should seek an alternative disposal site and, in the interim, have the waste discharge from Niven Lake disinfected. Such action will not remove all the bacterial pathogens or viruses that may be found in the study area, but should provide a great reduction in their numbers from the major source, the city's sewage.

If urban communities are to develop in the North, it is obvious that sewage disposal and water supply must be given high priority. Disposal of improperly treated wastes such as that found in Yellowknife should not be allowed; and, in the event that waters become contaminated, the users must be warned through adequate publicity, and the responsible authorities ensure that domestic use is either stopped, or precautionary measures taken.

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