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Commuting and exposure to airborne carcinogenicmaterials : a case study of Bangkok air pollution

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Commuting and exposure to airborne carcinogenic materials : a case study of Bangkok air pollution*

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Objective : *To study the level of exposure to carcinogenic carbon black and Benzo [a] pyrene that commuting individuals might receive in urban traffic.*

Setting : *Bangkok Metropolis.*

Subjects : *20 primary lung cancer patients and 20 normal subjects.*

Design : *Experimental design by applying the direct measurement of air pollution.*

Method : *The first measurement of carbon black during commuting environment. Commuting patterns, which included, namely: mode, time, route, distance and direction, were imitated by 3 volunteers during June – August 2001. Filter papers of Pollution Control Department at air monitoring sites at roadside collected during June 2000 – May 2001 was also used for BaP analysis.*

Results : *Lung cancer patients received higher load of carbon black when compared to the controls ($p < 0.05$). People who traveled by normal bus, motorcycle, main road, rush hours and those who spent more than 3 hours were more likely to get significantly higher concentration of carbon black. Additionally, residents, workers and commuters in the inner of the city may be exposed to BaP, which was higher than the safety limit.*

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Conclusions : *Commuting through certain modes and time spent in urban traffic were contributors to the risk of lung cancer among Bangkok residents. The continual exposure may lead to the carcinogenic health endpoint over time.*

Keywords : *Commuting, Carbon black, Benzo [a] pyrene, Bangkok.*

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วัตถุประสงค์ : *เพื่อต้องการศึกษาความสัมพันธ์ระหว่างพฤติกรรมการเดินทางกับการได้รับสารก่อมะเร็งที่เกิดขึ้นจากควันไอเสียรถยนต์*

สถานที่ที่ทำการศึกษา : *กรุงเทพมหานคร*

ผู้ที่ได้ทำการศึกษา : *ผู้ป่วยมะเร็งปอดจำนวน 20 ราย ประชากรทั่วไปจำนวน 20 ราย*

วิธีการศึกษา-วัดผล : *การวิจัยเชิงทดลอง โดยการวัดระดับสารก่อมะเร็งในบรรยากาศ ได้แก่ เขม่าและ Benzo [a] pyrene จากริมถนน ในการวัดระดับของเขม่านั้นใช้เครื่องมือวัดฝุ่นระดับบุคคล พร้อมหัวคัดแยกขนาดฝุ่นขนาดเล็กกว่า 10 ไมครอน โดยทำการเลียนแบบพฤติกรรมการเดินทางได้แก่ พาหนะ ระยะเวลา เส้นทาง ของ ผู้ป่วยมะเร็งปอดจำนวน 20 ราย และประชากรทั่วไป จำนวน 20 ราย ระยะเวลาที่ศึกษาระหว่างเดือนมิถุนายน – สิงหาคม พ.ศ. 2544 ในการวัดระดับของ Benzo [a] pyrene ได้ทำการวิเคราะห์จากการตรวจวัดฝุ่นขนาดเล็กกว่า 10 ไมครอน จากสถานีตรวจวัดอากาศริมถนน ซึ่งดำเนินการโดยกรมควบคุมมลพิษ กระทรวงวิทยาศาสตร์ เทคโนโลยีและสิ่งแวดล้อม ระหว่างเดือนมิถุนายน 2543 – พฤษภาคม 2544*

ผลการศึกษา : *ผู้ป่วยมะเร็งปอดได้รับเขม่ามากกว่าประชากรทั่วไป ผู้ที่เดินทางด้วยรถเมล์ธรรมดา, มอเตอร์ไซค์, เดินทางในช่วงเวลาเร่งด่วน, อยู่บนถนนสายหลัก และใช้เวลาเดินทางมากกว่า 3 ชั่วโมงมีโอกาสที่จะได้รับเขม่ามากกว่าผู้ที่เดินทางด้วยการเดินหรือจักรยานและ/หรือเดินทางบนถนนสายรอง นอกจากนี้จากการวิเคราะห์ปริมาณสารก่อมะเร็ง Benzo [a] pyrene พบว่าผู้เดินทาง ผู้ที่ทำงานและผู้ที่อยู่อาศัยในเขตกรุงเทพชั้นในมีโอกาสที่จะได้รับสาร Benzo [a] pyrene ในระดับที่สูงกว่ามาตรฐานความปลอดภัย*

วิจารณ์และสรุป : *พฤติกรรมการเดินทาง โดยเฉพาะพาหนะและระยะเวลาที่เดินทางอยู่ในการจราจรที่ติดขัดเป็นปัจจัยเสริมเพิ่มโอกาสเสี่ยงต่อการเป็นโรคมะเร็งปอดได้*

คำสำคัญ : *การเดินทาง, เขม่า, Benzo [a] pyrene, กรุงเทพมหานคร*

It is well documented that the quality of air in Bangkok Metropolis and municipal areas is in severe degradation. This is because of the increasing air pollutants, and their levels are higher than safety standard. [1] It is resulted mainly from the number of vehicles as well as factories. [2] Moreover, crowded communities and high-rise buildings, which tend to block wind and sunbeams, lead to poor ventilation and also the decline of green areas in the city and lower natural capacity in reducing air pollution. It is expected that indoor air pollution, especially in public vehicle is affected by outdoor air pollution, and it gets even worse in crowded vehicles.

The total daily exposure of individuals to air pollution in the urban area was experienced by individuals passing through a series of microenvironment, both outdoor and indoor, and also depended on the time spent in the environment. One of the microenvironment that people were exposed to air pollution was during their commutes. Unplanned urbanization of Bangkok has lead to high levels of commuting and severe traffic congestion.[3,4] Generally, most commuting patterns take individuals from an relatively low air polluted area to higher hazardous outdoor polluted areas. [5] Moreover, during the journey, people traveling in vehicles are probably more exposed to air particulate and other pollutants emitted by the vehicles. In addition, the majority of people living and working in Bangkok metropolitan areas and the nearby provinces regarded buses as their regular mode of transportation. Averagely, 3.4 millions people use the service everyday. [6]

Since particulate matter has been dramatically increased in the City of Bangkok and more than 50 percent are generated by congested traffic. Bangkok residents and commuters have been exposed to these fine particulate from the road-traffic which is harmful not only because of its small size, but also because of its chemical components. Carbon black and Benzo [a] pyrene, important chemical components of vehicle emission, are considered human carcinogenic health endpoint. [7] Benzo [a] pyrene, as a toxic air contaminant, is a five-ring Polycyclic Aromatic Hydrocarbon found in combustion-generated respirable particles collected from sources like motor vehicle exhaustion, smoke from residential wood combustion, fly ash from coal-fired power plants and other combustion related processes. [8] BaP is a larger group of complex mixture, e.g. soot, tar and oil. Office of Environmental Health Hazard Assessment (1994) concluded that air concentration at ambient, BaP might cause or contribute to an increase in mortality or serious illness and may therefore pose a potential hazard to human health. [9] The International Agency for Research on Cancer considers BaP as known animal carcinogen and human carcinogen (group 1)[7]; with inhalation unit risk 8.7 $[ng/m^{-3}]^{-1}$ U.S. Environmental Protection Agency also classified BaP as possible human carcinogen (Group B2).[9] The California Air Resource Board (1994) reported that BaP was emitted into the air in California. 35 percent of the total was contributed by mobile sources.[9]

As Bangkok is the biggest urban area of Thailand, it has been hypothesized that Bangkok commuters who spend time in urban traffic are exposed to high load of airborne carcinogenic materials, both carbon black and BaP. The level of exposure could be different in relation to the mode, time of commuting, time spent and its routing in urban traffic. In order to evaluate the level of exposure to these airborne carcinogenic materials during commuting and its contribution to the risk of lung cancer, the aim of this research is to study the level of exposure of carbon black at the individual level and BaP concentration at the roadside, and the find out whether or not commuting contributed to the risk of lung cancer of residents in Bangkok.

Materials and methods

The measurement of the concentration of carcinogenic materials was carbon black during commuting and BaP analysis of roadside environments were applied in this study. A preliminary experiment was set up, based on a subset of 20 lung cancer patients and 20 other healthy persons from general population, to explore the level of exposure to airborne carcinogenic materials that commuting could contribute to individuals during commuting. This subset was randomly selected from a case-control study entitled "Air Pollution and Lung Cancer: A Case Study of Bangkok Residents" undertaken by the Institute for Population and Social Research, 2001, in which the respondents were 132 primary lung cancer patients and 296 members of the general public. The concentration of carbon black in collected air particulate matter was investigated in this study by direct measurement methods for 40 different commuting routes. Both of these measures are associated with black smoke, in particular the fine particulate matter fraction, which is capable of penetrating deep into the lung. The objective was to study the level of exposure to carcinogenic materials associated with airborne particulate materials that all 40 cases received from their commuting, both going out and coming home through urban traffic. The current measurements were purposed to surrogate the level of exposure that individuals might receive.

Their commuting pattern included: mode, time, route, distance and direction, which were actualized by 3 volunteers during June – August 2001. The PM10 was collected by using 3.7 mm of PVC filter paper with a personal pump monitor and it was operated under the flow rate of 1.7 lt/minute. The commuting modes were, namely: walking, bicycling, automobile, bus, train and boat. The commuting directions were classified as major and minor roads, inbound and outbound. Each route of cases and controls were studied and imitated for three different days by three volunteers. The detail of each route was assigned to each volunteer. They did not know whether the imitation was case or control. Each case was imitated in three different days. The filter papers were weighted before and after the experiment and kept in a desicator to eliminate humidity for 24 hours. A reflectometer was used to analyze carbon black from the PM10 filter papers.

The principle of operation of the reflectometer is based on the degrees of light absorption and light reflectance. With higher carbon black masses on the filter, lower percentages of the light are reflected. The quality control was made by testing the same sample repeatedly afterward; the average of the percentage of light reflectance would be later calculated. The reflectance percentage was then calculated into logarithm scale, -log (Reflectance of sample/reflectance of Blank). A calibration curve from a standard set of filters was prepared. The regression equation, Y = 0.0044X and correlation coefficient, R square = 0.9806, were obtained. Note that Y = -log (Reflectance of sample/reflectance of Blank), X = Black Carbon mass (μg). From this relationship, the total mass exposure was determined. The concentration of carbon black in the air (μg/m^3) was calculated by dividing the mass by the air sampling volume.

A second investigation of Benzo [a] pyrene (BaP), known carcinogenic and toxic materials, was concerned with their ambient concentrations at key locations for commuters. The primary source of BaP in most urban environments is from engine combustion and hence their concentrations are associated with traffic densities. The samples were collected by the Thai Pollution Control Department during June 2000 – June 2001. Four air monitoring stations at inner urban sites which were either on the roadside or near-roadside were selected, namely: Dindang roadside; Ministry of Science, Technology and Environment (MSTE); Department of Land Transport (DLT); and Chulalongkorn Hospital (CH). The fifth site, Bangkok University (BU) was selected as a better representative of the outer zone of Bangkok. The sampling sites are shown in Figure 1.

Results

An Analysis of Carbon black

The results from Table 1 showed that 50% of lung cancer cases spent more than 3 hours/day in urban traffic. This result is consistent with the carbon black analysis (Table 2). The concentration of carbon black was related to the time spent and lung cancer cases were more likely to be exposed to black smoke than the controls ($p < 0.05$).

There are some modes of transportation with very few cases that cannot be analyzed, which are, namely: air-conditioned buses, automobiles, pickup trucks, trains, and vans. Therefore, motorcycles, normal buses, bicycles, walking, and boating, would need further investigations (Table 3).

The results from Table 3 showed that the concentration of carbon black was statistically related to the mode of transport, in particular normal buses and motorcycles. Lung cancer cases who traveled with normal buses and motorcycles are more likely to get a higher load of carbon black compared to

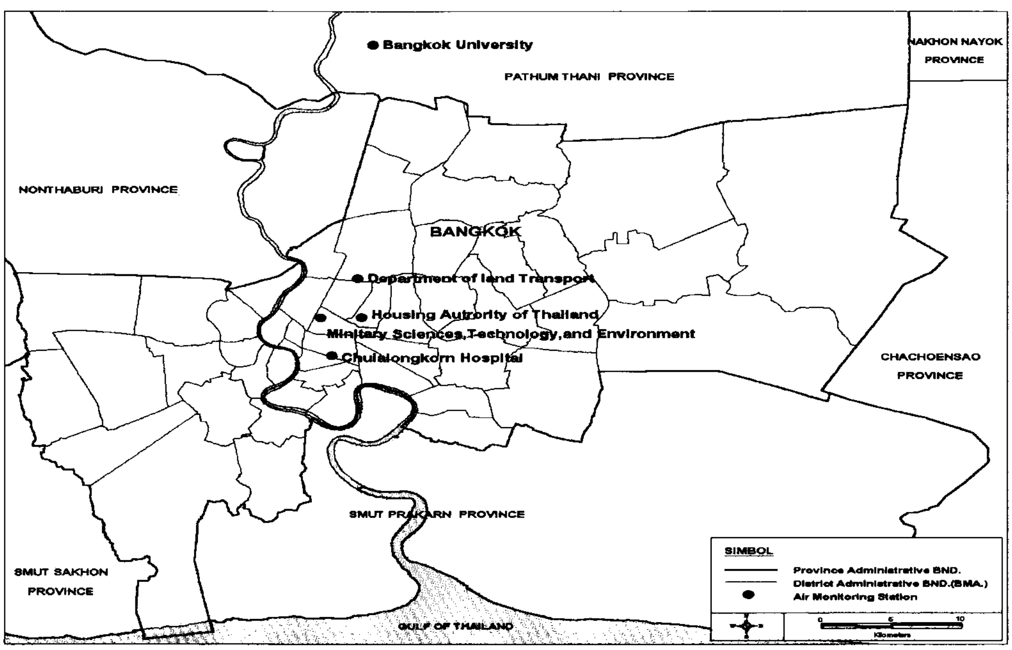

Figure 1. Locations of five monitoring stations.

Table 1. Percentage distribution of sample classified by time spent in urban traffic (Based on 20 lung cancer patients and 20 healthy subjects from general population)

	Lung cancer patients	General population
Time spent in urban traffic/day		
< 1 hr	20.0	25.0
1 – 3 hrs	30.0	40.0
> 3 hrs	50.0	35.0
Total (n)	100.0 (20)	100.0 (20)

Table 2. Rank comparison of carbon black mass and carbon black concentration with separation of going-out and coming-home periods.

Carbon black	Type	N	Range	Means Rank	Mann-Whitney U	Sig
Concentration	Case	20	.00-2.48	46.6	594	0.04
($\mu g/m^3$)	Control	20	.00-1.07	35.3		
Mass (μg)	Case	20	.00-69.01	41.2	771	0.78
	Control	20	.00-61.09	39.7		

the controls. Time spent in urban traffic was also associated with the load of carbon black particularly when it was less than 2 hours. Lung cancer cases who spent less than 2 hours in urban traffic were more likely to be exposed to carbon black than those exposed for more than 2 hours. This might be affected by the route of traveling. Most cases of lung cancer spent more time along main roads with congested traffic.

Considering the route of commuting (Table 3), traveling by main roads was significantly related to the concentration of carbon black ($P < 0.05$). Particularly, lung cancer patients were more likely to be exposed to higher loads of carbon black than the controls. Carbon black was also related to the time of commuting, whether they traveled during the rush hours or not. In this study, the rush hours were defined as 2 periods which were 6.30 – 9.00 a.m. and 4.30 – 7.30 p.m. It was found that no matter how they traveled during the rush hours, lung cancer cases were more likely to be exposed to higher loads of carbon black when compared to the controls.

Table 3. Rank comparison of carbon black concentration ($\mu g/m^3$) both of in and out bounds, classified by mode, time spent, route and time at commuting in urban traffic (hr).

		N	Range	MeansRank	Mann-Whitney U	Sig
Mode						
Bicycle	Case	2	.0-.06	2.25	1.5	.68
	Control	2	.0-.01	2.75		
Walking	Case	2	.08-.12	8.0	3	.19
	Control	8	.06-.11	5.0		
Boat	Case	2	.00-.01	3.0	1	.44
	Control	2	.00-.03	2.0		
Motorcycle	Case	12	.13-2.07	15.6	11	.00
	Control	10	.00-.64	6.0		
Normal bus	Case	10	.01-1.52	12.3	12	.01
	Control	8	.00-.15	6.0		
Time spent in urban traffic						
Less than 2 hrs	Case	26	.00-1.74	35.6	309	.04
	Control	34	.00-.48	26.6		
Equal to or more than 2 hrs	Case	14	.00-2.07	11.0	35	.56
	Control	6	.00-.19	9.3		
Route						
Main road	Case	34	.00-2.07	35.0	315	.04
	Control	27	.00-.64	25.7		
Minor road	Case	6	.00-.58	10.0	38	.96
	Control	13	.00-.48	10.0		
Time at commuting						
rush hour	Case	30	.08-2.17	29.0	199	.04
	Control	21	.00-.48	20.4		
Non rush hour	Case	10	.00-1.17	20.1	44	.02
	Control	19	.00-.25	12.3		

Note: 40 routes; 80 filters: 40 filters for in bound and 40 filters for out bound.

An Analysis of Benzo [a] pyrene

As shown in Figure 2, the Benzo(a)Pyrene (BaP) average concentration at a roadside environment such as Chulalongkorn Hospital was the highest followed by the Ministry of Science, Technology and Environment, Dindang, and the Department of Land Transport with concentrations of 4.5, 4.3, 4.1, and 3.4 ng/m,[3] respectively. These four sites were located on or closely adjacent to busy roads in the inner zone of Bangkok. Regarding Bangkok University, which is a permanent air monitoring station set up for measuring regional background air, the concentration of BaP was the lowest (2.7. ng/m^3). The explanations of these relativities are supported by the study of the distribution of PAHs in an urban roadway in Brisbane, Australia (Pathirana *et al.*, 1994) which looked at 16 PAHs, including BaP. The total PAHs concentrations decreased with the increased distance from the roads. The study suggests that an air monitoring site located in a general area far from a main road, such as Bangkok University, might expect to have lower BaP concentrations than those located along roadsides in the center of the city.

Since these five monitoring stations covered the origins, and destinations and routes of 20 lung cancer cases and the 20 controls, this finding meant that all of them were exposed to the same level of BaP which was higher than safety limit. Additionally, the population being exposed to this level of BaP included the non-commuters, people who lived and worked in those areas.

In this study, the BaP of each monitoring site was an average value calculated for dry and wet season. These values were consistent with the study of IARC, 1983. It was found that in ambient air, BaP is normally associated with fine particulate. It was reported that in the atmospheric concentration, BaP in summer in urban areas was averagely 3.6 ng/m^3. In the winter, the concentration is higher with an average of around 7.1 ng/m^3. To the extent of which the safety limits were set by OEHHA, U.S. EPA and WHO, the average BaP concentration for all sites was lower than the standard unit of WHO (8.7 ng/m^3) [7] but it was detrimental and exceeded the range of inhalation unit risk of OEHHA [9] (1.1-3.3 ng/m^3) and U.S. EPA (1.7 ng/m^3).

The roadside environment is a part of most commuting routes where the commuters are exposed to mixtures of chemicals in the air which come mainly from engine combustion associated with congested traffic. BaP, a human carcinogen, was found to be higher than acceptable safety limit (Figure 2); and

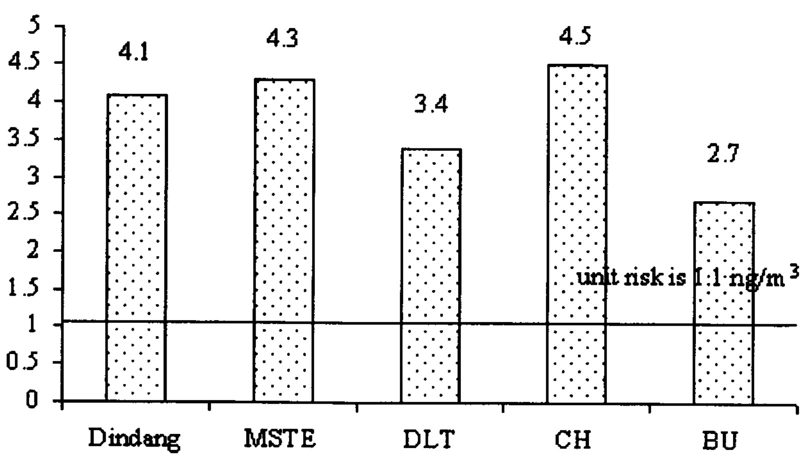

Figure 2. Average concentration of BaP at the 5 sites, June 00 – May 01.

this highlights the potential harmfulness of the air for the commuters who travel on these roads. These findings can be used as surrogate levels of carcinogenic BaP, exposure that the individual might received along a commuter route.

Conclusion and discussion

The exposure to carbon black for long time will cause to the respiratory morbidity and decreased lung function.[11] Anyway, no research had done about the exposure to carbon black and impact on health during commuting. The studies usually undertake in the enclosed area such as factory. The longitudinal European study found that there is elevated risk for respiratory diseases as was shown by decreased of lung function for 1.3 – 1.4 folds for every increase of 1 mg/m^3 of carbon black [14]. However, the estimation of cancer risk from hazardous air pollution is very difficult because of lacking of data.

From the results of BaP and carbon black, more cases than controls travel on a busy road closed to an air monitoring stations at roadside and therefore these lung cancer cases have a higher potentiality to be exposed to a higher load of carbon black than the general population. Similarly, the study the measuring concentrations of selected air pollutants inside vehicle in California revealed that carbon black level measuring in a carpool lane were much higher than the slower lane. In addition, in-vehicle pollutant concentrations obtained from freeway were higher than the minor road. However, type of vehicle was shown to have little effect to the carbon black level[15]As the studies of BaP and the carbon black showed that they are mainly generated by incomplete combustion of vehicles, these findings imply that the exposure to airborne carcinogenic materials the excess risk of lung cancer is more likely to occur in those who spent time in urban traffics. This includes commuters, traffic policemen, street venders, transport workers and people who dwell close to a congested road.

Some tentative conclusions on exposure and pollutant loads for commuters can be drawn for the contributing role of commuting to the risk of lung cancer. From these investigations, commuting in urban traffic is likely a contributor to enhance the risk of lung cancer. It depends on time spent, mode, and direction of people traveling in urban traffic. The exposure is expected to be higher if the modes of traveling are more risky such as normal buses or motor cycles, even it last for a short time. It is recognized that very small sizes of sample have been taken and care needed to be considered in comparing these sets of data. Any observation and conclusion need to be seen as merely tentative.

As mentioned above, there are implications from these findings, which can also be drawn for a stationary roadside population. These roadside exposures are very dependent on some identified factors and they would appear to warrant further definition and consideration.

It is apparent that traffic congestion and vehicle maintenance are most important considerations to estimate the pollutant load to which a commuter might be exposed. The load of carbon black and exposure to carcinogenic benzo [a] pyrene emission was found to be dangerous to human health. Additionally, it may lead to carcinogenic health end point across time. Strategies, which are aimed to address these two aspects, such as creating an environment of free-flow commuting routes that require regular maintenance and vehicle emission monitoring, are likely to have the greatest benefits to the health of the commuters.

This study suggests that there may be health (and economic) benefits if the appropriate authorities were to organize traffic pollution awareness campaigns so that the population who need to commute in highly polluted areas will have more concern and greater awareness. Better educated commuters and roadside residents would be able to make judgments about the values and types of protective measures that might be taken.

The findings showed that commuting time of more than three hours especially in rush hour was related to lung cancer risk. The government is trying to improve economic growth but, in turn, this has the potential to result in more people being able to be car owners and living further from their place of work. More cars, more commuting and finally more pollution on the road will impact the population's health. As information technology is not well developed so that people can work at home, people need to commute from home to offices. Commuting time needs to be reduced by providing safe, fast, cheap, convenient, and less polluted mass transportation systems.

Therefore, commuting, in particular its mode and time spent in urban traffic, may be considered a contributor to the risk of lung cancer among Bangkok residents. The main recommendation from this study is that the public should enforce the reduction of the exposure by reducing the emission from the vehicles on the road, in particular public buses and motorcycles. Further, for future researches should focus on fine particulate matter and associated chemicals and their relationship to chronic respiratory disease and the relative influence of the enclosed compartments such as air-conditioned buses, cars and other modes of commuting.

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