

Research on the Factors of Recreational Diving Safety Accidents—Based on the Improved HFACS1

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Abstract: *Nowadays, the frequent occurrence of recreational diving safety accidents has severely affected the reputation of the industry. This paper is based on the improved Human Factor Analysis and Classification System HFACS1, and finds that unsafe behavior, precursors of unsafe behavior, unsafe supervision, and organization are suitable as structural elements of the analytical framework. The “flaws” of the secondary indicator at the four levels finally lead to irreversible safety accidents due to the violations. After reflecting on the current domestic situation, this paper organizes the recreational diving prevention strategy as follows: 1) Make anonymous violation cases included in the grade examination materials for reference; 2) The four main related members including the divers, diving partners, diving guides and diving clubs work jointly to build a good safety environment; 3) The diving organizations need to conduct standardized overhaul and management on the diving clubs. 4) Establishing and perfect the channels of multi-level organizational supervision. And proper preventive measures for four-level flaws will effectively reduce the occurrence of safety accidents.*

Keywords: Recreational diving, Safety accidents, The Human Factor Analysis and Classification System, Factors, Preventive measures.

1. INTRODUCTION

Recreational diving refers to a leisure sport using diving equipment for snorkeling under or above the water. It is a comprehensive recreational sport with a combination of sports, viewing, entertainment and tourism[1]. Recreational diving has been popular among many diving enthusiasts in China and has huge economic benefits. The annual increase in the number of Open Water Diver Certificate (OW) issued by Professional Association of Diving Instructors (PADI) is approximately 50%[2]. The Wuzhizhou Island Tourism Area in Sanya City had a turnover of 960 million yuan in 2016, of which 40% was associated with recreational diving[3]. However, the reputation of this industry is seriously hit by recreational diving safety accidents happening from time to time. Therefore, it is of practical significance to systematically study the influencing factors of recreational diving safety accidents.

Previous studies on the influencing factors of safety accidents were limited to a certain reason or focused on several safety links namely “before recreational diving”, “before entering the water”, “during diving” and “after diving”[4], or only on how much importance diving clubs attach to safety[5], which is slightly one-sided and lacking theoretical perspective. Therefore, based on the improved Human Factor Analysis and Classification System (HFACS1), this article strives to restore the influencing factors of the complete chain of accident events, and deeply reflects on the domestic current situation and develops prevention strategies.

2. IMPROVED HUMAN FACTOR ANALYSIS AND CLASSIFICATION SYSTEM (HFACS1) AND ITS DECONSTRUCTION

2.1 Theoretical Basis of Human Factor Analysis and Classification System (HFACS1)

James Reason, Professor at the University of Manchester, England, proposed the “REASON Model” (also called the “Swiss Cheese Model”[6]) in *Human Error* based on the relevant theories of many famous scholars. This model, with a systematic perspective, reveals the occurrence of unsafe events related not only to the behaviors of people directly involved in the events (current failure), but also to organizational factors (potential failure) in other levels which are away from the events. The REASON Model believes that in an organization, the occurrence of the accidents is triggered by four levels of factors: organizational factors, unsafe supervision, portents of unsafe behaviors and unsafe behaviors. It compares the defects of four lines of defense to the loopholes in four pieces of cheese. At some point, four levels of loopholes happen to arrange in a straight line, which will lead to dangerous

safety accidents. In 1997, Wiegman and Shappel began to construct Human Factor Analysis and Classification System (HFACS) based on the REASON Model[7]. HFACS built a bridge between theory and practice, playing a significant role in American Navy's security data monitoring and measure intervention and reducing the proportion of accidents caused by violations (the most primary factor) by approximately 20 percentage points over 3 years[8]. In recent years, HFACS model has also been used in domestic fields such as civil aviation and medical science, which has made many research achievements. The successful application experience of HFACS is worth learning from. This paper presents the improved HFACS1 after combining authoritative interviews with domestic diving professionals (a schematic diagram of the framework is shown in Figure 1).

2.2 Deconstruction of the Improved HFACS1: the leading role of organizational factors

As shown in Figure 1, the improved HFACS1 covers 16 metrics of four levels of factors. In general, the organizational factors regulate all aspects of diving as the leading factor. By preventing the emergence of unsafe supervision, be warning of the portents of unsafe behaviors and reducing the occurrence of unsafe behaviors, it finally realizes the prevention of safety accidents. The resource management (Chinese diving organizations), one of the organizational factors, can play a role in managing unsafe supervision (clubs). The organization culture included can help divers, diving clubs and diving organizations effectively identify the precursor signals of unsafe behaviors, and plays a great role in establishing a safe diving environment. Organizational factors can effectively reduce the occurrence of divers' violations and mistakes during the whole operation process, and thus avoid the accidents.

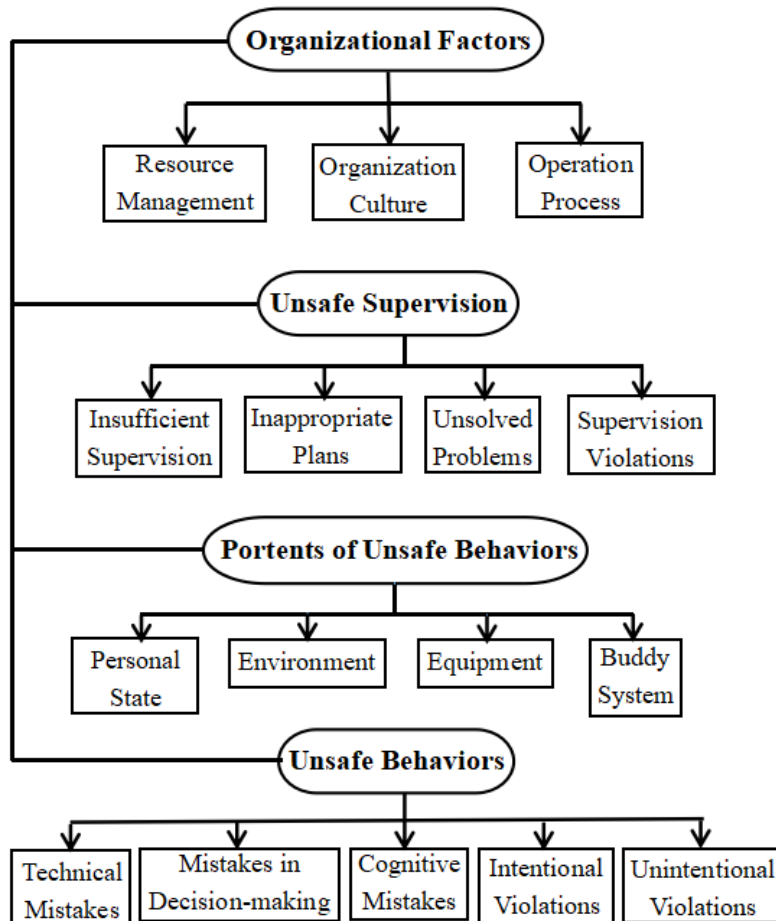


Figure 1: Schematic Diagram of the Improved HFACS1

3. INFLUENCING FACTORS OF RECREATIONAL DIVING SAFETY ACCIDENTS

3.1 Unsafe Behaviors: Personal Violations are the Most Direct Factor

Unsafe behaviors are roughly divided into two categories: mistakes and violations. Violations refer to divers' violations of safety regulations, including intentional violations and unintentional violations. Intentional violation

refers to the diver knowing the rules but still intending to violate the rules to dive without authorization in disregard of safety regulations and behavioral prohibitions. If divers insist entering the water without being familiar with the sea area and night diving, or take tourists into the sea without any gas cylinder or even obtaining a coaching license, then they violate the rules intentionally. Unintentional violation refers to irrational behaviors caused by people who may not understand the rules and regulations or wrongly understand the safety regulations. If the divers die due to negligently failing to check the cylinder valve before entering the water, it is an unintentional violation. Both intentional and unintentional violations are unsafe behaviors, the last defense line of four pieces of cheese and the most direct factor resulting in safety accidents.

3.2 Portents of Unsafe Behaviors: Personal State is Always the Main Vulnerability

The portents of unsafe behaviors caused by divers include four indexes: personal state, environment, buddy system and diving equipment. Among them, excluding the environment which is an uncontrollable factor, personal state is always the main influencing factor of this level. Personal state includes diver's personal limitations, physical state and mental state. Personal limitations refer to lacking of physical or psychological conditions to participate in recreational diving. Due to the connection between age and risk of hidden diseases, people under the age of 15 and over the age of 60 have hidden limitations. Those who are too young lack independent judgment, and those who are too old may have certain hidden physical diseases, leading to fatal accidents caused by adverse reactions underwater. Physical state includes physical examination report when obtaining a diving license and physical condition before each launch. People having physical illnesses such as carsickness, vomiting and having a cold are not supposed to go into the water. Mental state is a state affected by divers' negative emotions such as panic, anxiety and stress. Once divers find any peer diver having mental issues, they should pay more attention and take action to avoid tragedies. Therefore, at the portent level of unsafe behaviors, prevention and intervention should first be taken on individuals' adverse state.

3.3 Unsafe Supervision: Problems Like Clubs' Dereliction of Duty in Supervision and Inappropriate Operation Plans are Prominent

In diving activities, inadequate supervision of diving clubs, inappropriate operation plans, no reminders of known issues and no strict examinations are all unsafe supervision. It has been proved that well-trained operators can conduct adequate preliminary safety supervision to effectively reduce the risk of safety accidents[9]. Inadequate supervision refers to the club staff's dereliction of duty. Additionally, the clubs' inappropriate operation plans will also increase the flaws at the unsafe supervision level. Inappropriate operation plans refer to putting the operator in danger due to unreasonable work arrangements. Each diving plan requires negotiation and cooperation from divers, diving partners, submersible guides and diving enterprises (clubs). The degree of difficulty, risk, monthly phase time, necessary equipment (such as current hook for large flows, surface marker buoys in different sizes for different places, diving watches that are bright enough for places with poor visibility, etc.) should be included in the exercise plans to prepare for bad situations. In addition, an appropriate backup medical plan is required to determine the location and contact information of the nearby decompression chamber, to purchase insurance according to the location of the decompression chamber, and to master the way of local emergency transportation. Therefore, divers, diving partners, submersible guides and diving clubs should make diving plans with mutual agreement and close cooperation.

3.4 Organizational Factors: Organizational Defects are Hidden Dangers

James Reason believed that among the contribution factors of accidents, the biggest hidden risks which are far from the accidents in time and space are those of recessive errors in the system. Recessive errors not only contain the portents of the unsafe behaviors mentioned above, but also specifically refer to the failure of organizational factors. When no failure of unsafe supervision occurs, organizational factors do not appear threatening to the safety of the system and are therefore difficult to be detected[8]. And when looking for the cause of the accident, those unsafe behaviors considered as "triggers" of the accident are more easily identified as the cause of the accident, while potential management failures are often ignored[10]. The management level directly affects the attitude and behaviors of the operators. Organizational errors are often ignored by people, and people fail to realize that organizational defects are an important cause of errors and accidents[11]. It is clear that organizational defects are the most fundamental hidden cause in these cases.

4. PREVENTION STRATEGIES FOR RECREATIONAL DIVING SAFETY ACCIDENTS

4.1 Unsafe Behaviors

4.1.1 Domestic Status Quo: the access threshold of practitioners is constantly increasing

At present, in addition to domestic experiential recreational diving, club diving and spontaneous diving practitioners need the systematic learning of standardized, scientific and international diving theories and technologies, and only after obtaining different levels of internationally-accepted diving certification, can they own, borrow or rent diving equipment to participate in diving activities. Since 2012, the diving social sports instructor has officially become the legal qualification certification personnel of recreational diving in China. In the theoretical study of diving grade certificate, theoretical and case study should be strengthened to prevent the occurrence of unsafe behaviors, and we should also develop standardized and strict diving operation habits.

4.1.2 Prevention Strategy: make anonymous violation cases included in the grade examination materials for reference

Under the guidance and support of the Water Sports Management Center of the General Administration of Sport of China, the China Water Ski, Underwater & Powerboat Federation has strictly standardized and systematically carried out the grading tests of domestic recreational diving step by step. Domestic diving license examination systems are mainly divided into two kinds, whether it is for recreational diving coaches, athletes and other technical professions, or mainly for the public, is recommended to add the anonymously-processed warning cases of personal violation to grading materials of each diving test. At the same time, the access threshold should be strictly checked, and the examiners must strictly comply with the grading standards for evaluation and identification. It also needs to be strictly supervised after the certificates are issued, and divers are supposed to abide by the level of their own qualification certificate, and be alert to the illegal “red line”. Hence adding the anonymous warning cases of personal violation to grading materials is conducive to reducing the occurrence of individual violations.

4.2 Portents of Unsafe Behaviors

4.2.1 Domestic Status Quo: the safety awareness of divers needs to be improved

Be in awe of the sea. On the one hand, divers are required to have a clear understanding of the requirements for participating in diving. Only by maintaining a good physical state can they meet the high requirements for diving. On the other hand, divers are required to keep alert to the complex and changeable underwater environment. Take Southeast Asia, the accident location in the case, for example. Located in the tropics, Southeast Asia is very suitable for marine tourism activities like snorkeling with high-quality sea water, and has been a popular place for Chinese citizens to travel abroad. But the low technical requirement for snorkeling and poor local management weaken tourists' safety awareness. These human factors directly lead to participants and organizers' wrong prediction of the weather, environmental factors (changes of underwater currents caused by tidal changes, rainy weather and frequent typhoons in summer, etc.) were ignored, laying a hidden danger for diving activities.

4.2.2 Prevention Strategy: the four main related members including the divers, diving partners, diving guides and diving clubs work jointly to build a good safety environment

According to the improved HFACS1 model, a safe environment built by well-established diving organizations, standardized diving clubs, qualified divers and experienced submersible guides can effectively prevent the occurrence of safety accidents. The joint cultivation of diving organizations, clubs, divers and submersible guides allows every practitioner, not only coaches, but also club practitioners, especially divers, to have prediction and emergency plans on the weather and sea surface conditions during diving. When diving, all sides need to have a comprehensive understanding of the sea current and typhoon conditions in the diving environment. Divers should fully understand their own physical and mental state and physical limitations, even if a little emotional discomfort is felt, they should decisively stop participating underwater activities. There is a saying about diving, “never dive alone”, indicating a basic rule of diving— diving partners should check each other. All sides ought to pay much attention to the role of diving partners and prevent divers from entering the water alone. Integrate the safety awareness into diving and jointly optimize the safety environment.

4.3 Unsafe Supervision

4.3.1 Domestic Status Quo: industry access requirements are strict, but the “black shops” in the gray area still exist

Diving clubs must be approved by Chinese Underwater Association to carry out diving activities and to issue diving certifications for a certain international organization, and it must be examined and verified by municipal sports bureaus to obtain open licenses for diving activities and management licenses for sports of high risk, and finally it must be registered and verified through bureaus of industry and commerce to run diving training. But some small-scale diving clubs do not have these qualifications, which turn into “black shops”. These unqualified clubs blur the nature of their operation and attribute leasing equipment and unauthorized opening of diving waters to purely personal behaviors, thus shirking responsibility.

4.3.2 Prevention Strategy: the diving organizations need to conduct standardized overhaul and management on the diving clubs

Some coastal cities in China have taken corresponding measures to the usual means of informal clubs to standardize and industrialize them. Sanya not only has a clear application process, but also a more strict supervision system. Relevant industries organize inspection every year and publicize illegal enterprises and individuals. Once behaviors like cheating customers and offering substandard service show up, enterprises and individuals involved will be immediately placed on the blacklist. These measures are worth learning from, and standardizing and industrializing the clubs and registering in the China Water Ski, Underwater & Powerboat Federation as required are necessary measures to eliminate safety hazards. It is imperative for diving organizations to rectify and manage the diving clubs.

4.4 Organizational Factors

4.4.1 Domestic Status Quo: diving organizations do not conduct multilevel organizational supervision

From the perspective of the construction of rules and regulations, China has not yet formed a safety management system and regulations with legal effect which can restrict the recreational diving industry according to law. Relevant Chinese diving organizations or associations should change the status of “stragglers and disbanded soldiers” when performing their duties, and provincial and municipal diving associations shall carry out high-level organization and supervision through various work such as progressive management, communication and guidance. In addition, successful associations should be replicated and promoted within the industry. Established in November 2018, Shenzhen Dapeng New District Diving Association, the first domestic district-level diving association, has issued 36 risk warnings to the registered clubs and member units in the association and carried out safety management under climate conditions and the requirements of government functions, to ensure the zero occurrence of safety accidents in the registered clubs of the association so far. Thus, multilevel organizational regulation can start with district-level associations.

4.4.2 Prevention Strategy: establishing and perfect the channels of multi-level organizational supervision

China’s recreational diving industry has been developing, and by now, diving clubs have had the main characteristics of scattered distribution and regional concentration in terms of layout, and have basically formed five developed diving areas: Beijing and Bohai Bay Area, Shanghai and East China Area, Guangdong and Hainan Area, Southwest and Hong Kong, Macao and Taiwan regions of China Area. Relevant Chinese diving organizations should focus on supporting these five areas and optimize the sea environment there to attract domestic tourists to participate in diving. We can also upgrade the progressive key experimental area—“District-level, Municipal, Provincial and National Water Ski, Underwater & Powerboat Federation” with the focus of these five areas, thus making the domestic diving organizations to form a management and deployment effect of “using the minority to bring along the majority”. The district-level diving associations can be the smallest unit to carry out unified organization and standardized management of the registered clubs within the area and conduct routine inspections. Clubs shall investigate the coaches, divers and practitioners in accordance with the rules and regulations. The staff of associations at all levels shall be urged to cultivate good professional quality and safety awareness, and regular inspection and spot check actions shall be conducted to timely find and eliminate the hidden dangers in the associations.

5. CONCLUSION

This article restores the complete chain model of accidents by using the improved HFACH1 model (see Figure 1). The results showed that a single factor will not directly lead to a fatal accident. After the occurrence of unsafe behaviors, the lack of the other factors jointly result in the safety accidents. The defects of organizational factors as hidden ones bury hidden dangers for safety, and the occurrence of unsafe behaviors break through the last line of defense. At the same time, the lack of prediction of unsafe behaviors is disguised to encourage unsafe behaviors, and the lack of clubs' supervision also directly exacerbates the safety risks.

In order for recreational diving, a popular tourism sport, to develop continuously in China, the diving industry must minimize fatal accidents to the utmost. It is not enough for the diving industry to only take targeted prevention against individuals or clubs to increase the defense capability of each line of defense. Therefore, in the future, the diving industry must also start from the organizational factors, improve the rules and regulations of recreational diving, strengthen the safety awareness and education of practitioners in the diving industry and standardize the professional operation of practitioners in clubs, so that they will obey the organization and management of the associations, and effectively ensure the safety of recreational diving.

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