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RISK ANALYSIS AND EVALUATION OF THE CURRENT SITUATION IN TERMS OF WORK SAFETY IN THE DRINKING WATER TREATMENT PLANT

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Abstract: Water treatment plants are the most important facilities used to provide potable water to settlements and clean water. These facilities raise water quality to the desired standards physically, bacteriologically, and chemically. A conventional drinking water treatment plant consists of aeration, coagulation, flocculation, settling, filtration and disinfection units. Each of these units has its hazards. For this reason, if adequate safety precautions are not taken, the possibility of plant employees being, exposed to these hazards will be quite high. Risks arise as a result of exposure to hazards in every workplace. It is important to analyze these risks and determine the precautionary priorities and to ensure health and safety in the workplace. In this study, the hazards that employees may be exposed to in a drinking water treatment plant in the Eastern Black Sea region were determined. All the units of the facility were examined and all risks that would affect the employees and the working order of the facility were calculated with the matrix method. After the risk levels have been determined, in the study the risks named as unacceptable and as to be considered are presented and the precautions to be taken in the facility are listed to be protected from these risks. As a result of the study, the importance of personal protection measures and safety culture, especially collective protection measures, was emphasized for the employees in such workplaces containing complex units.

Keywords: Water treatment plants, Clean water, Drinking water treatment plant, Hazard, Risk analysis

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1. Introduction

Along with the advances in industry and technology, as a result of changes in production tools and processes, health and safety problems increase as well as the risks that employees are exposed to. Taking health and safety measures to eliminate these problems is only possible with the conscious implementation and execution of relevant regulations and scientific methods. By minimizing work accidents and occupational diseases, regulations create a healthy and safe working environment for employees and protect the future of both employees and their dependents (Tekbaş, 2013). Poor working conditions can cause loss of products and materials in the workplace, damage to work equipment, and most importantly, injuries, illnesses, loss of limbs, and death of qualified and trained employees. Conceptually, occupational safety is defined as the technical rules that determine the obligations of the employer to eliminate or reduce the existing hazards in the workplace (Demircioğlu and Centel, 2007).

When workplace accidents are examined, it has been determined that 80% of these accidents are caused by dangerous behaviors and 18% are caused by dangerous situations in the working environment. According to these data, it is concluded that employers and employees should be sensitive about occupational health and safety and fulfill their duties duly. The first step in creating a safe workplace is risk assessment for which the employer is responsible.

There are two types of approaches to risk analysis: reactive and proactive. In the reactive approach, it is ensured that the system is not repeated by intervening after the accident occurs, while the proactive approach is based on predicting and preventing the risks that may occur before the accident (Özkılıç, 2007).

According to the Occupational Health and Safety Law, which entered into force on 2013, it is among the general obligations of employers to carry out or have risk assessments in the workplace (Anonymous, 2021). By this law, it has become clear that employers who exhibit reactive behavior should now take a proactive approach.

Water Treatment Plant is an infrastructure facility that guarantees human and environmental health and plays a key role in providing healthy clean water access to the community (Spellman, 2003). For this reason, it is very

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important to carry out risk analysis against both external and internal dangers, to protect the process, to take the necessary precautions in the equipment, and,, to inform and train the employees (Çakmakçı et al., 2013).

In the risk assessment, first of all, potential dangers that may occur during the activities of a workplace that produces or provide services or that may come from outside are defined. Then a risk analysis is carried out. The main purpose of risk analysis is to estimate the magnitude of risk in all processes in the workplace and to decide whether the existing risk will be acceptable. Finally, it is ensured that control measures are taken regarding the risks found and that death, injury, and health deterioration are minimized (Özkılıç, 2005).

Drinking water safety is the ability to effectively protect against the negative effects of chemical, microbiological and radioactive pollutants at every stage where the source of drinking water passes from the feeding area until it reaches the final consumer. In addition to the quality of drinking water by TS 266 standards, it is necessary for drinking water safety that the drinking water network flow is sufficient (Ertaş and Sarımehmetoğlu, 2019). To guarantee drinking water safety permanently, each process in such plants contains risks for the employees.

Dangers to be encountered in drinking water treatment plants are listed below:

1.1. Dangers of Accidents

Slips, falls and yaws on wet and slippery ground levels during the withdrawal of water; falls from height while climbing or while standing in an elevated industrial installation, and falls due to working with faulty ladders; falling into an industrial installation or water well during the inspection and/or taking water samples for analysis; injuries caused by being caught in work clothes or a part of the body between parts of unprotected moving machinery; electric shock due to contact with active cables or faulty electrical installations, (the danger is usually quite high because the work is done in a wet or humid environment); exposure to dangerous substances due to the sudden release of toxic substances as a result of an accidental or human-induced situation, such as the addition of chemicals to an unsuitable installation, (for example, the release of chlorine gas due to the addition of disinfectants such as hypochlorite burning in aluminum sulfate); fires due to improper storage of chemicals, contact of a flammable chemical with a strong oxidant (disinfectant) as a result of sudden release from the pipes in the process; dangers of explosion as a result of contact with ozone (a very strong oxidant), organic chemicals and a strong reducing agent; dangers of drowning when working in reservoirs or channels with strong currents; dangers of drowning when carrying out maintenance or installation works such as working in a closed space (tank, boiler) or while performing excavation works (collapse of tunnel or excavation area) (Çakmakçı and Özkaya, 2013).

1.2. Physical Dangers

Exposure to high noise levels caused by electromechanical equipment and a noisy environment; exposure to adverse weather conditions: being exposed to the risk of colds as a result of working in rain, low temperatures and windy weather, and excessive sweating in summer; exposure to UV rays during water disinfection, may be damaging to the eyes and skin (Anonymous, 2009).

1.3. Chemical Dangers

It is the exposure to different disinfectants used for water disinfection. These are listed below:

1.3.1. Chlorine (gas)

Chlorine is the most preferred disinfectant type in drinking water treatment (Al-Otoum et al., 2016). Chlorine is preferred because it is cheap and easy to operate. It is a very strong oxidizer and disinfectant. It is a toxic and corrosive gas that causes irritates in the eyes and respiratory system even at low concentrations (Özgür, 2021).

1.3.2. Hydrochloric acid

It is a very strong acid used in water treatment processes, especially in the reverse osmosis system, which is one of the drinking water processes, to lower the pH value of the water. It causes severe skin burns and eye damage if swallowed, in contact with skin or inhaled.

1.3.3. Sodium hypochlorite (NaOCl)

It is used as a solution in water purification as a disinfectant. Permanent irritations occur in case of exposure to the solution. The substance is toxic and corrosive in certain parts of the respiratory system. It irritates the eyes and skin and causes burns.

1.3.4. Calcium hypochlorite

It is a type of hypochlorite shown with the formula $Ca(ClO)_2$. It is used in water purification and pool cleaning systems in daily life. In case of skin contact, serious skin damage with blistering and wound; in case of swallowing, it causes burns in the mouth and throat, severe nausea, vomiting, shortness of breath and shock. It has a corrosive effect even when diluted. It is toxic to aquatic organisms.

1.3.5. Ozone

It is an oxidizing and irritating disinfectant; when inhaled, it causes breathing difficulties, headaches, fatigue, eye irritation, tearing and inflammation. It does not dissolve in nature by itself. It also oxidizes substances that are extremely dangerous to human health, such as iron, manganese, and arsenic in the water. It should be used with another disinfectant that has the feature of being a residual disinfectant (Uzun, 2011).

1.3.6. Chlorine dioxide

It is a disinfectant with proven effectiveness and is widely used internationally, which has a lethal effect on bacteria, mold, yeast and viruses. It is 2.5 times more effective than other disinfectants (both reacting and killing microorganisms). While chlorine produces carcinogenic substances when used excessively in waters with organic residues, chlorine dioxide does not create such an environment. It is approved by the USA and "EPA" for drinking water disinfection.

1.3.7. Aluminium Sulfate

One of the drinking water treatment stages is the "coagulation" stage, which ensures that various substances and particles in the water are retained and removed from the water by precipitation after this retention, and aluminium salts are used at this stage. This step helps to reduce the level of organic matter, turbidity and microorganisms in the water, and removes colour problems. Commonly used aluminium compounds for this purpose are aluminum sulfate and polyaluminium chloride. Aluminium sulfate has been used for a long time in the treatment of surface waters (Srinivasan et al., 1999; WHO, 2003). It irritates in case of contact with eyes and inhalation, mild irritation in case of contact with skin, and irritation of mucous membranes in the mouth, throat, esophagus and gastrointestinal tract if swallowed

1.3.8. Potassium permanganate

It is used in drinking water treatment plants to purify water. It can strengthen the fire; it is an oxidizing agent. Suspected of damaging fertility or the unborn child. Harmful if swallowed. It has a long lasting and very toxic effect on the aquatic environment.

1.4. Identification of Gas Dangers

Gas dangers in drinking water treatment plants contain chlorine, sulfur dioxide, ammonia, ozone and chlorine dioxide from places such as gas storage areas, gas dosing plants and ozone generators. These gasses constitute the highest danger group as they trigger many things such as industrial disasters that can endanger human life and the environment and must be effectively monitored in the working environment. Chlorine is a very heavy gas and is easily absorbed by many materials that make it difficult to detect in landfills.

1.5. Ergonomic, Psychosocial and Administrative Dangers

Musculoskeletal disorders occur due to working in inappropriate postures during installation or cleaning of the piping system; when lifting or moving heavy and large loads, excessive strain affects different parts of the body; psychological tension and pressure occur due to environmental factors such as disturbing noise, splashing water, odor, high humidity etc. Due to increased workload, the continued need for high skill levels, increased work efficiency requirements, lack of privacy due to increased opportunities for supervisors to reach the worker (cell phones, especially after normal working hours) and commitment to unexpected calls during emergencies, the need to work overtime shifts psychosocial problems arise. It causes psychological problems (especially for older workers) caused by adaptation to computer-based jobs (Vasović et al., 2018).

In this study, a risk assessment was carried out in a drinking water treatment plant located in a province in the Eastern Black Sea region. In the light of the information collected from the plant, dangers were identified, and possible risks were determined. According to the results of the risk analysis, recommendations were made on sustainable and effective measures to ensure occupational health and safety.

2. Materials and Methods

In a province of the Eastern Black Sea Region (the name of the facility cannot be given due to confidentiality principles), the potential hazards that the workers in the drinking water treatment plant may be exposed to within the scope of occupational health and safety were determined and a risk assessment was made.

2.1. Facility Introduction

Drinking water needs are met from caisson wells in the city, with a pumped system. The rapidly increasing population of the city, the expiration of the existing wells and the need for better quality drinking water made it necessary to search for new water sources. The facility, the construction of which was started by İller Bank in 1987, was completed and put into service in 1992. The area where the facility is established is 100,000 m^2. The water of the facility, which has been meeting the water needs of the city and its surroundings since 1992, was supplied by the regulator of the existing stream. The fact that the stream from which the water is supplied is located in the city center and the risk of being very close to the highway and the increasing water need of the city necessitated new searches and brought the construction of a dam to the agenda and in 1998, the foundation of the dam was laid, and work started. However, considering that the construction of the dam would take time to complete, a regulator was built downstream of the dam as a temporary measure and the stream's water was connected to the treatment plants in 2001 with a 2700-meter transmission line. Since 1992, when the treatment plants were put into service, quality drinking and utility water needed by the city has been provided by TS266 drinking water standards (Karagüzel et al., 2003). There are 10 units available at the facility. These are respectively Water intake structures, Raw water transmission lines, Water distribution structure, Flowmeter, Coagulation and Mixing structure, Clarifiers, Filtration, Chlorination Unit, Contact Tank, Clean water tank, and Clean water transmission line.

2.2. Risk Assessment Method

In this study, a 5x5 Type Matrix (L Type) method was chosen in order to evaluate the risk for the employees of the treatment plant. The reason for choosing this method is that it can be used by a single analyst, and it enables rapid grading of risks according to different levels of importance. In this, first of all, the risk degree is obtained by multiplying the probability of occurrence of a detected hazard with its severity in case of realization (Equation 1). Each parameter takes values in the range of 1 to 5. According to the risk level result, it is determined that the risk levels are intolerable, significant, moderate, bearable and unimportant. Then, the risks are listed starting from the highest value and the necessary precautions to be taken are determined (Anonymous, 2016).

$$Risk = Probability * Severity \quad (1)$$

In this study, the risk ratings obtained as a result of risk analysis were categorized as follows: Inadmissible Risk if Probability * Severity ≥ 15
Risk to be Considered if 8 ≤ Probability * Severity < 15
Acceptable Risk if Probability * Severity < 8.

2.3. Danger Identification

According to the risk analysis regulation (ÇSGB, 2012); after determining the authorities who will conduct the risk analysis, it is necessary to define the dangers that may come from outside or that exist inside. As a result of the risk analysis, the dangers that will pose the highest risk are listed as follows:

1. There are deformations and irregularities on the ground throughout the facility, and irregular material storage has been made that will cause tripping and falling.
2. There is a wet floor problem throughout the facility.
3. Electrical panels are exposed and it is being worked with unsuitable electrical cables.
4. There is an emergency action plan at the facility, but it is seen that the training received by the facility employees about what to do in an emergency is insufficient.
5. The ventilation is not operated continuously.
6. Periodic inspections of measuring devices, machinery and equipment used in the facility were delayed due to workload, lack of attention, etc.
7. It has been observed that the personnel working within the facility do not usually use personal protective equipment.
8. There are deficiencies in the training of employees about occupational safety, diseases that they may catch, safe working methods and hygiene.
9. The thermal comfort condition of the facility employees are high, and especially in adverse weather conditions, factors such as snow, ice and rain cause slips and falls.
10. It is observed that careless operation and safety precautions are ignored during maintenance and repair works.
11. There is a danger of O2 deficiency and accumulation of toxic gas in closed areas.
12. There are areas in the units where there is a risk of fire and explosion.
13. There is a danger that facility employees may exhibit unsafe behavior (carelessness, fatigue, difficulty in understanding, etc.).
14. There is a danger that the emergency exit doors are not fully equipped in the facility.
15. The mud floor scraper is not closed and there is a risk of falling from a height, electric shock and exposure to biological agents.
16. It has been observed that the materials are left in the facility irregularly.
17. The sound of the backwash pump causes noise.

3. Results

Risk analysis studies carried out in the drinking water treatment plant units were carried out by considering the interviews with the administrators and technical personnel and previous studies.

3.1. Risk Assessment

When the entire facility was examined, a risk analysis was made according to the identified dangers. According to the results of the risk analysis, the risks that are unacceptable and need to be considered and their degrees are shown in the Table 1 below.

Table 1. Drinking water treatment plant risk analysis table

Activity	Danger and Risk	Possibility	Severity	RDS	Assessment
General	Sliding fall and injury as a result of not taking the necessaryprecautions in the cleaning areas	4	3	12	Risk to be considered
	As a result of the temporary staff starting to work withoutvisiting the OHS unit, accident, injury and material damage because they do not have enough information about thefacility.	3	4	12	Risk to be considered
	Failure to use personal protective equipment, occupationaldisease, injury, death	4	5	20	Unacceptable Risk
	Stuck and fall injury due to uneven facility floor	4	4	16	Unacceptable Risk
	O_2 deficiency, increase in toxic gases, suffocation, death, especially in indoor environments as a result of inadequateventilation	4	5	20	Unacceptable Risk
	Stumbling and injury as a result of irregular placement oftools, equipment and materials in the facility	4	3	12	Risk to be considered
	Misuse and injury, material damage as a result of theabsence of machine operating instructions	4	5	20	Unacceptable Risk

Table 1. Drinking water treatment plant risk analysis table (continue)

Activity	Danger and Risk	Possibility	Severity	RDS	Assessment
Warehouses	Flash, explosion, fire and injury, death, property damage as aresult of random storage of the stored materials without separating them according to their types.	4	5	20	Unacceptable Risk
	The floor of the chemical warehouse is not easy to clean,exposure to chemicals, occupational disease, material damage	4	4	16	Unacceptable Risk
	Growth of fire, explosion, injury, death, property damage asa result of the lack of sufficient fire extinguishers in the warehouses	3	4	12	Risk to be considered
Welding works	Injury, loss of limb, death as a result of electric shock fromelectrode welding current generators in the welded areas	3	5	15	Unacceptable Risk
	Failure to respond to an emergency and injury due to theabsence of a fire extinguisher in the welded area	3	4	12	Risk to be considered
Electricity	Electricity leakage due to wear in the energy input and output lines of the machine and current flow, injury, loss oflimb, death.	4	5	20	Unacceptable Risk
	Electric shock, injury, loss of limb, death as a result of contact with unauthorized persons due to leaving electricalpanels open	5	5	25	Unacceptable Risk
Emergency	As a result of not specifying the emergency escape routes and the presence of materials on the roads, confusion andinjury in the event of an emergency	3	4	12	Risk to be considered
	Failure to respond to the fire in a timely manner, injury, property damage as a result of installing fire extinguishers inplaces that are not easily accessible	4	4	16	Unacceptable Risk
	Inability to reach the safe area due to the absence of emergency lighting, which should be activated in case of anemergency, or if there is a power cut.	3	4	12	Risk to be considered
	Confusion, injury, death as a result of uneducated and notknowing what to do in the event of an emergency.	4	5	20	Unacceptable Risk
Units	Falling, injury, drowning, death as a result of not taking thenecessary precautions in the clarifier and filter pools	3	5	15	Unacceptable Risk
	Inhalation of chlorine by the operating operator as a resultof possible entry into the flow meter compartment, poisoning, death	3	5	15	Unacceptable Risk
	Inhalation of harmful air, poisoning as a result of cleaningthe sludge accumulated in the raw water channel at the accelerator inlet (1 per month)	4	4	16	Unacceptable Risk
	Injury, limb rupture due to exposure to rotating parts in theturbine gearbox	2	4	8	Risk to be considered
	Hearing loss as a result of the backwash pump making noise	3	4	12	Risk to be considered
Lifting tools	Falling of the load, injury, death, material damage as a resultof not specifying the load capacities on the overhead cranes,forklifts, chain hoists, pallet trucks, etc.	3	5	15	Unacceptable Risk
Laboratory	Respiratory diseases, skin wounds as a result of inhalation ofstrong acid vapor in the laboratory and skin contact	3	3	9	Risk to be considered

In order to make risk analysis more efficient and not to overlook existing hazards, facility activities are divided into 8 groups as General activities, Warehouse, Welding works, Electricity, Emergency, Units, Lifting vehicles and Laboratory. According to the obtained risk analysis results, the activities that may result in serious injury and death are listed in Table 1. As a result of the study, a risk assessment was carried out to protect the occupational health and safety of the employees at the drinking water treatment plant in a province in the Eastern Black Sea region. The 5x5 matrix method was used in the risk analysis phase, which was carried out under risk assessment. According to the results of the analysis, the risk levels were calculated, and these risk levels were grouped as unacceptable/to be considered/acceptable risk. A total of 125 dangers were determined at the facility and their risk levels were calculated. Since the risk level of 100 of them has been determined at an acceptable level and adequate protection measures have been taken in the current situation, only continuous control and follow-up is recommended. The remaining 25 risks were considered unacceptable and should be considered. The necessary protection measures are listed below.

3.1.1. In the "unacceptable risk" category

It is necessary to ensure that the person enters the work area with personal protective equipment by the determined standards and the work they do. Railings should be built around the gaps formed on the working floor or their tops should be closed temporarily. Items and other obstacles on the passageways should be removed against the risk of tripping/falling. Irregularities (subsidence and bends) on the ground should be removed.

In order not to cause poisoning and fire/explosion, it is necessary to ensure that the indoor areas, unit entrances (flow meter compartment and raw water channel entrances) and tanks have adequate ventilation. It should be ensured that systems such as gas detectors are installed for the measurement of toxic/flammable/explosive gasses leaking into the environment. The operating instructions for all the machines used should be provided immediately and they should be hung in visible and suitable places.

In the warehouses, the cabinets and shelves should be fixed to the floor and/or the wall, their weight bearing capacities should be written in the visible places, and in the case of chemical materials, they should be separated according to their types. Care should be taken to ensure that the floor of the warehouse is not affected by the spillage of the stored material and is easy to clean. Earthing of electrode current generators during welding must be done against electric shocks. Before starting to work with the machines, the cables should be checked for electrical leakage and if necessary, unauthorized persons should be prevented from contacting the machine by tagging/locking.

All electrical panels should be kept locked and only authorized persons should be able to access them. It is necessary to have enough fire extinguishers suitable for their type in the workplace, to install warning signs indicating their locations, be placed in easily accessible places, and check their expiration dates and fullness. Emergency drills should be carried out at the periods specified in the legislation, employees should know how to act when faced with such a situation, and who the emergency teams consist of.

All pools in the facility for purification and clarification should be surrounded by guardrails and unauthorized persons should be prevented from entering the area. The load capacity that can be carried on the lifting vehicles should be specified and the equipment should be operated in a way that does not exceed this value.

3.1.2. In the "risk to be considered" category

To protect the employees, the noise source caused by the backwash pump should be isolated or the pump that causes less noise should be preferred. If this cannot be done, employees should be provided with appropriate ear protection.

Facility employees should prefer work clothes that are not too loose in order not to get caught in the machines during work; appropriate head protection should be used. All moving parts of the equipment (turbine gear, etc.) that may injure the worker must be protected. In case of studies that produce toxic gas in the laboratory, fume hoods should be used or the employees should use gas masks. Personal protective equipment should be used before coming into contact with materials.

It should be ensured that the emergency lightings showing the emergency exit directions are activated in case of a power failure and remain on for at least 2 hours. Emergency escape routes must be shown with warning signs, and there must be no material obstructing the escape routes. All personnel who come on temporary duty should be informed about the facility and working order. Necessary qualification documents, health records, and the training they received (occupational health and safety, occupational, etc.) should be questioned. Preventing slips and falls after cleaning in the workplace is possible with precautions such as the use of non-slip boots/shoes by employees and careful cleaning services procedures.

4. Discussion and Conclusion

Workplaces such as drinking water treatment plants contain very complex processes and risky areas. For this reason, it is very important to examine them carefully in terms of occupational health and safety, to take collective protection measures first, to gain the habits of using personal protective equipment to eliminate increasing risks, and most important to develop a safety culture in the workplace. The way to progress is possible by being sensitive to people and the environment. By this way, the productivity of the workforce will increase and since the health and safety of the employee are ensured, the conscientious responsibility will be fulfilled.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	H.B.Ö.	C.G.S.	A.U.
C	30	30	40
D	30	30	40
S	30	30	40
DCP	30	30	40
DAI	30	30	40
L	30	30	40
W	30	30	40
CR	30	30	40
SR	30	30	40
PM	30	30	40
FA	30	30	40

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

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