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Management Process of Oil Spill in Water Plants

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Abstract

The protection of the water intakes is very essential to insure the safety of the drinking water, safe effort, time, increase the water purification system performance and to make the customer satisfied. One of the ways to make this aim on the land is taking an action to prevent the water pollution by spilled oil.

Cairo Water Company activated a management program throughout the institution to provide a sustainable protection of the drinking water from the contamination by oil, throughout the protection of the water intakes and moreover the action will take place if any oil spread out into the clarifiers or filters. This report includes a scope on the sources of the petroleum pollution and the level of responses, also a documentation of an accident happened in 2008.

Keywords: Water pollution; Spilled oil; Level of responses; Activated program; Sources of the petroleum pollution; Sustainable protection

Introduction

Water pollution is an undesirable change in the state of water, contaminated with harmful substances. Polluted water is not only unsafe for drinking and other consumption purposes, but it is also unsuitable for agricultural and industrial uses.

With expansion of the oil business the level of environmental pollution risk is inevitably increasing. Ruptured oil pipelines, ship collisions or groundings, overfilling of gas tanks, bilge pumping from ships, leaking underground storage tanks, oil-contaminated runoff from streets and parking lots during rain storm are considered from the environmental oil pollutions [1].

"Oil and water do not mix", but when oil spills in water, toxic chemicals from the oil mix with the water and stay there for a long time. Cleanup and recovery from an oil spill is difficult and depend upon many factors, including the type of oil, the temperature of the water (affecting evaporation and biodegradation) and the types of shorelines and beaches involved [2].

So, the aims of the present work are to give a great description on the behavior of spilled oil, give a wide scope on the levels of response and to transfer the oil spill's management program to use it in a similar situation elsewhere.

Behavior of Oil Spill in the Marine Environment

By observing the thickness of the film of oil and its appearance on the surface of the water, it is possible to estimate the quantity of oil spilled. If the surface area of the spill is also known, the total volume of the oil can be calculated [3]. As oil moves through the marine environment, a variety of physical and chemical processes can occur that whether and alter the oil, including biodegradation, evaporation, dissolution, emulsification/dispersion, and photo-oxidation [4].

Spreading

Spreading of crude oil on water is probably the most important process following a spill. Spreading is affected by wind, waves and currents.

Under the influence of hydrostatic and surface forces, the oil spreads quickly attaining average thickness of less than 0.03 mm within 24 h the oil layer becomes fragmented by wind and waves into islands (The Basics of Marine Oil Spill Response).

Evaporation

Evaporation and dissolution are the major processes, degrading petroleum crude when spilled on water factors effect on evaporation rate are composition of oil, its surface area physical properties, wind velocity, air and sea temperatures, turbulence and intensity of solar radiation, alone will remove about 50% of hydrocarbons. Loss of volatile hydrocarbons increases the density and the kinematic viscosity of oil lead to breakup of slick into smaller patches [5].

Photo-oxidation

The natural sunlight in the presence of oxygen can transform several petroleum hydrocarbons into hydroxyl-compounds such as aldehydes and ketones and ultimately to low molecular weight carboxylic acids, as the products are hydrophilic, they change the solubility behavior of the spill [6].

Dispersion

Dispersion is oil-in-water emulsion resulting from the incorporation of small globules of oil into water Colum oil begins dispersing immediately on contact with water. It is important to compute the natural dispersion in order to evaluate the life time of an oil spill which depends on environmental parameters, but is also influenced by oil related parameters such as oil thickness and its properties (eg. density, surface tension, and viscosity). Emulsification will also contribute to

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persistence of oil spilled, mainly due to increasing the viscosity and slick thickness, causing retarded spreading, increasing volume that will reduce natural dispersion [7].

Dissolution

Is another physical process in which the low molecular weight hydrocarbons as well as polar non-hydrocarbon compounds are partially lost from the oil to the water column and increase water media toxicity? However, the evaporation is faster than the dissolution, as shown in figure 1, so most of those chemicals will evaporate quickly, thus the amount of crude oil dissolved in water is there for typically small (less than 5%) or even nonexistent in certain cases (Figure 2) [9].

Degradation

Bio-degradation processes influencing fate of petroleum in aquatic environment include microbial degradation, ingestion by zooplankton and uptake by aquatic invertebrates and vertebrates. Microorganisms capable of oxidizing petroleum hydrocarbons and the related compounds are widespread in nature. However, this is a slow process because it depends on nutrients and oxygen availability and can be limited by the presence of toxic pollutants [10].

So, if there is a spill it will:

1. Move by diffusion
2. Spread to form a thin layer
3. Lighter compounds will evaporate
4. Non soluble compounds will become emulsified and dispersed in the water column and
5. Degradation and photo-oxidation will occur depending on the contamination [11].

Bad effects of oil spill

Oil forms a thin layer on top of water and act like a lid, which forms oil-in water emulsion or floating film, animals and plants living in the water can't breathe, the oil coats the feathers of water birds, preventing it from foraging or escaping from predators and the fur of animals that swim in the water, causing them to become sick and, if there is a great amount of oil on their bodies, to die by irritating the digestive tract, altering liver function, and causing kidney damage even the insects that live on the surface of the water are badly affected [12].

Moreover, crude oil entering waterways from spills or runoff contain polycyclic aromatic hydrocarbons (PAHs), the most toxic components of oil. Fish exposed to these PAHs exhibit an array of toxic effects including genetic damage, morphological deformities, altered growth and development, decreased body size, inhibited swimming abilities and mortality result in significantly reduced survival in fish due to the reduction of swimming and feeding abilities [13-15].

Oil spills can also harm air quality [16]. The chemicals in crude oil are mostly hydrocarbons that contain toxic chemicals such as benzenes, toluene, oxygenated polycyclic aromatic hydrocarbons and poly-aromatic hydrocarbon.

These chemicals can introduce adverse health effects when being inhaled into human body [17]. On the other hand, toxic components in oil may exert their effects on man through inhibition of protein synthesis, nerve synapse function and disruption in membrane transport system and damage to plasma membrane, resulting in carcinogenesis, mutagenesis and impairment of reproductive capacity, volatile components of crude oil after a spill have been implicated in the aggravation of asthma, bronchitis and accelerating aging of the lungs [5].

How to keep safe after an oil spill

1. Avoid contact with the oil. Keep children and animals away from the spill. If possible, put a fence around the area and post a warning sign.
2. Use a source of water upstream from the spill.
3. Avoid eating animals that live in water near the spill and areas downstream.
4. Avoid bathing in affected water. If somebody falls in the water, they should wash right away with strong soap and clean water.
5. Teach people about the dangers of oil at schools and community gatherings.

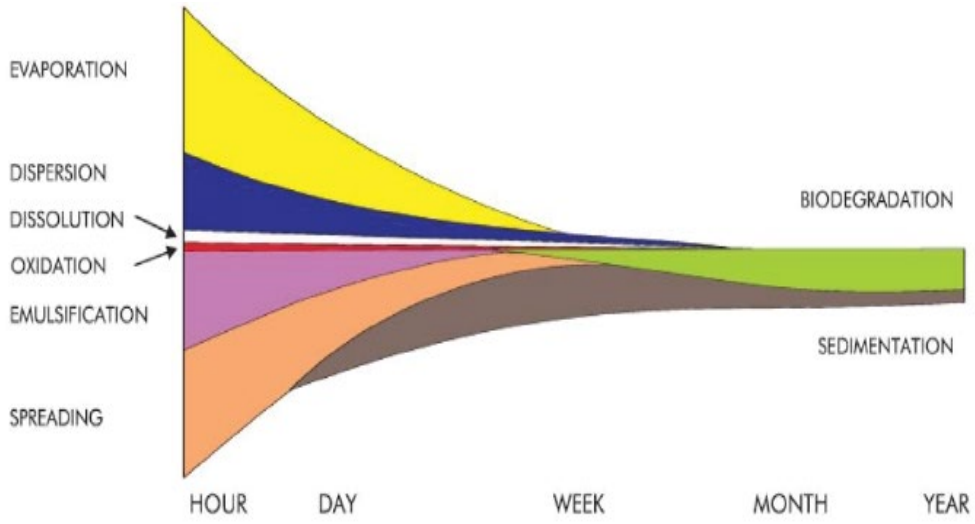

Figure 1: Time scale for oil weathering (and hydrocarbons in general) [8].

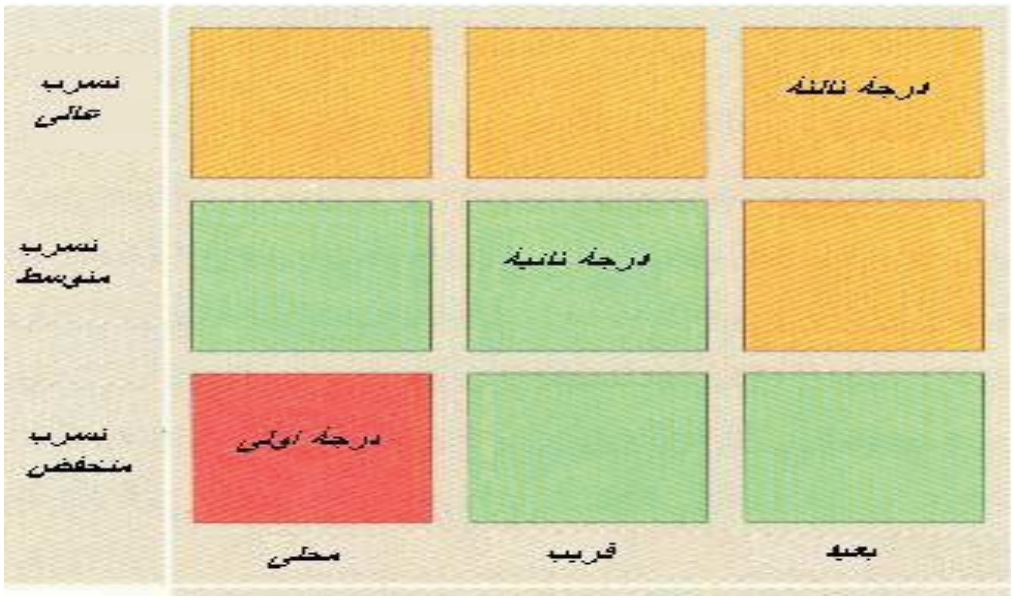

Figure 2: Levels of response towards the oil spill.

Response to Oil Pollution

Public policy

The proposed policy to combat any petroleum pollution is based on the following principles:

1. Stop the leakage of oil from its source or reduce the rate of leakage.
2. Protect environmentally sensitive areas according to their importance and prepare environmental protection plan.
3. Try to combat and trapping the oil spill in water by mechanical means.

Levels of responses

Size, location and quantity of the oil as well as the time of the occurrence of the pollution considered as a difficult event to be predicted. Moreover, Cleanup and recovery from an oil spill is difficult and depends upon many factors, including the type of oil spilled, the temperature of the water (affecting evaporation and biodegradation), and the types of shorelines and beaches involved [18].

As a result of the risks of oil pollution, an action required to classify the size of pollution and identify its position by possibilities available in company, and this leads to the principle: "The reaction is according to the level of the event". So, Cairo Water company seeks to develop its response capacity to deal with all incidents at all levels by taking into account the different equipment's, well trained persons for each level and according to the type of each operation, as well as the type of oil and the surrounding environment.

Table 1 represented the levels of responses and the location of the pollution. It is clear that level (1), which is near the working area of the company, is controllable by the company equipment's.

Information gathering and risk analysis

Table 2 and Table 3.

Level	Location of pollution	Response
Tier 1	In the working area of the company.	The company carries out the control through the uses of its equipment.
Tier 2	Adjacent to the company's business area and the size and level of pollution is greater than the capacity and the means of the company.	Leads to the request for help from other local authorities.
Tier 3	The size and level of pollution is significant.	Requires intervention and assistance from many state bodies and intervention may be required neighbors countries and other bodies.

Table 1: Levels of response.

No.	Areas under risk	Type of pollutant
1	Intakes	Crude Oil Heavy oil (IF-0380)
2	Suction pumps	
3	Clarifiers	
4	Sand filters	

Table 2: Areas threatened by petroleum contaminants.

No.	The source of pollutions	Affiliates
1	Pipe lines	Petroleum companies
2	Boats and River barges	Tourism sector, and River transportations
3	The output of electrical companies	Electrical companies
4	Petroleum refining	Petroleum companies
5	The outputs of the factories all over the Nile River	Governmental and private companies

Table 3: Pollution's sources.

Tier (1) & (2) Response Action Plan

The use of various sorbent is the most common technique to treat floating oil on water surface because of the possibility of its collection and reuse [19]. Sorbents work on two principles: absorption and adsorption. In most cases sorbent materials are broadcast upon an oil spot and float along its surface until they become saturated with oil then the oil-soaked sorbents must be recovered and disposed.

In simple terms absorbents serve to soak up spilled products by capillary action. These types of sorbents resemble sponges in both form and function, and are ideal for low viscosity oil and fuel spills on land or water.

The deployment of sorbent is very easy and quick due to the weight of the sorbent is not heavy and the connection is very easy and didn't take more time.

Sorbent materials and Storage condition

The sorbent provided from "Pisco company" is made of rice straw (natural organic materials) and is effective in any weather condition due to its weight buoyancy ratio and its hydroscopic nature "doesn't absorb fresh or salt water". The container of the sorbent must be ventilated and the ventilation must be closed in adverse weather (i.e. rain); the container should be kept dry; wooden pallets to be placed in the bottom of the container under the sorbent. The container should be store at least 10 meters away from sources of heat or open fire. Moreover, direct sun rays are also prohibited. It is also prohibited to store together with flammables and tanks with flammable gases.

Usage of the sorbent

1. Connect the metal clips in each section to another section to increase the length (as each section is 3 meters long) on the deck before starting deploying the sorbet boom as shown in Figure 3.
2. Line up the connected sorbent on deck in a zigzag form (Figure 4).
3. Tie the first and last sections of the sorbent boom with a rope (10-15 meters length each).
4. The loose end of the rope tied to the first section of the sorbent boom is to be tied to the support vessel, and the loose end of the rope tied to the last section of the sorbent boom is to be tied to the vessel with sorbents.
5. The support vessel is to tow the sorbent booms around the polluted area to contain the spill (Figure 5 and 6).
6. Caution is to be taken not to disturb the oil on the water surface with the turbulence caused by the movement of the support vessel.
7. Use the sorbent pads to collect the spillage from the water surface (Figure 7).

Figure 3: Metal clips link sorbent booms together for extra length.

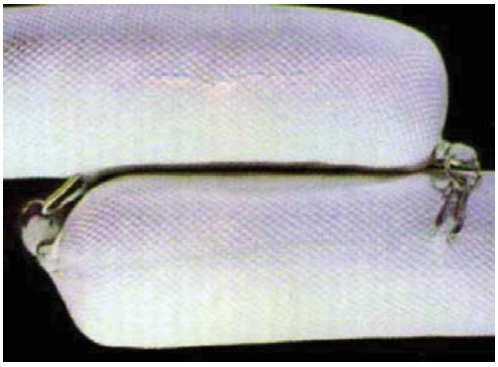

Figure 4: Technique to facilitate deployment of sorbents.

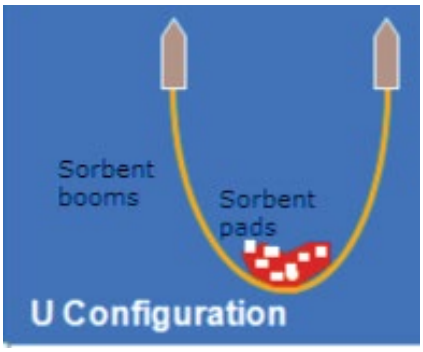

Figure 5: U-Containment shape.

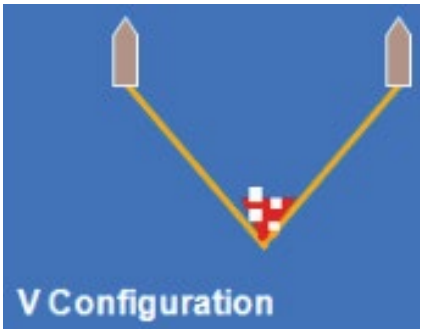

Figure 6: V-Containment shape.

Figure 7: Spread the sorbent pads on the surface to collect the spillage.

SOPs of Response Plan

1. The Cairo Water company takes several actions for preventing the leakage of fuel into the water outlet.
2. Reporting to the governmental official agencies for speedy action such as Ministry of Water Resources and Irrigation, Ministry of Housing, Ministry of Environmental Affairs, Helwan Governorate, Civil Protection department, Petroleum Gas Company and The security of the state.
3. Closing the inlet of the water plants or decreasing the number of suction pumps.
4. Insulating the water inlet of the water station by oil sorbent, using the oil sorbent to control of the oil spot and prevent it from farther spreading.
5. Reopening of the inlet of water plant and make sure that it does not reach to the outlet.
6. There is a scenario, even when there is an escaping portion of the oil spot into clarifiers and/or sand filters to protect the outlet water from pollution.
7. A team work from the central lab of Cairo Water Company taking environmental samples for analysis to be insured of the water safety.
8. The company will ask for an auxiliary help, if the oil spill is over the capacity of the company.

Protection of clarifiers outlet: action plan

The speed of the water plays a significant role in oil removal. So, in the flash mixing zone of the clarifier, the speed of the water prevents the oil from forming a layer on the surface of the water and the layer of the oil separated into small droplets (Figure 8) and the oil removal will be difficult in this area of the clarifier.

In the American and Czech clarifiers, the slow mixing zone with slow water speed allows the oil to form a layer on the water surface and the oil spots can spread as a layer on the water surface. Moreover the oil layer can transfer to the sedimentation zone and sand filters. Spreading the sorbent pads on the surface of the water in slow mixing zone of the clarifiers will absorb the oil layers and prevent them from farther spreading (Figure 9).

Pulsator clarifiers have different designs, in which the sorbent materials spread over the surface of water in the distribution zone to get rid of the oil spots (Figure 10). The flash mixing zone in which the water speed prevents the accumulation of the oil spots as a layer on the water surface and the defiance of the oil spill is very difficult. On the other side, the oil spill can be removed from the pulse zone by spreading the sorbent on the water surface in this zone in which the speed of the water is relatively slow (Figure 11).

Figure 8: Flash mixing zone in the American and Czech clarifiers.

Figure 9: Slow mixing zone in the American and Czech clarifiers.

Figure 10: Distribution zone of Pulsator clarifier.

Figure 11: Pluse zone of Pulsator clarifier.

Dorr Oliver clarifiers, as shown in Figure 12, designed to have an overflow area in the sedimentation zone. So when there are a lot of oil spots and the situation is out of control beside the usage of the sorbent is useless or there is a need to a lot of sorbent, taken the advantage of the present of this area of overflow.

Open the inlet of raw water and close all the outlet valves, the water level will be increase in the clarifier and an overflow of the water with the oil spots will take place and removed to the drain pipeline (Figure 12).

The disadvantage of using this method is large quantities of clarified water and non-revenue water (NRW) been wasted. Otherwise, large quantities of oil spots have been removed without using any sorbent materials.

Protection of the sand filters: action plan

In some rapid sand filters, like in the Czech design, the inlets of the filters are looking like a gate and the waste drains are separate. In those types of filters, close the filtration valve and simply open the water inlet to over flow the water and let the water with the oil spots to remove to the drain (Figure 13).

The sand filters with the inlet and waste drain are very close to each other's; in the same place, like in the American design (Figure 14), the action plan will be takes place by close the inlet of the filter and the filtration valve, open the drain valve and allow the backwash with water only, by operating one washing pump, to overflow the water with the oil pots to remove to the drain.

Determination of the total Oil and Grease

Crude oil is a mixture of hydrocarbons with different chemical compositions. It contains hydrocarbons with long and short chains, paraffinic, naphthalenic, aromatics, greases, etc. [20]. To make it possible to quantitate these hydrocarbons rapidly and with less expense, a suitable liquid-liquid extraction method, FTIR EPA method 413.2/418.1, that uses Cyclohexane as the extraction solvent. Moreover, Collection, preservation and storage of the samples are carried out according to the standard methods for the examination of water and wastewater [21].

Figure 12: Dorr oliver clarifier with overflow area in sedimentation zone.

Figure 13: Sand filter with gate inlet and separate drain.

Figure 14: Sand filters with water inlet and waste drain in the same place.

Figure 15: Kafr altitude water plant.

Case Study on the Oil Spill Recovery

Description of the disaster

In 2008, At Kafr altitude, Tebbin and South Cairo Helwan's electrictrical station, the pipe line of the liquid diesel fuel was broken; this accident forced the workers at Helwan Cement Company to divert the liquids to the Nile water along with the stream of the Nile, causing an oil spot of surface area about 5 Km^2 at the area near Kafr altitude water plant (Figure 15) and spread tell reach North Helwan water plant of distance 7 Km in long. It lasted nearly three months from April to June. Moreover, the amount of the total oil into Nile water reached

Sample/month	River Nile water (mg L^{-1})	Tap water (mg L^{-1})
January		
Min	0.26	0.22
Max	0.31	0.25
χ±SD	0.27±0.01	0.24±0.01
February		
Min	0.36	0.31
Max	0.41	0.34
χ±SD	0.35±0.01	0.32±0.01
March		
Min	0.45	0.32
Max	0.48	0.41
χ±SD	0.43±0.01	0.35±0.01
April		
Min	14.45	0.22
Max	14.45	2.94
χ±SD	14.45±0.70	2.03±0.20
May		
Min	7.78	0.23
Max	8.12	0.4
χ±SD	7.65±0.05	1.03±0.03
June		
Min	0.96	0.33
Max	1.23	0.38
χ±SD	0.95±0.02	0.37±0.01
July		
Min	0.43	0.22
Max	0.56	0.31
χ±SD	0.41±0.03	0.29±0.01
August		
Min	0.34	0.26
Max	0.42	0.29
χ±SD	0.37±0.01	0.24±0.01
September		
Min	0.27	0.34
Max	0.31	0.35
χ±SD	0.28±0.01	0.34±0.01
October		
Min	0.42	0.31
Max	0.56	0.36
χ±SD	0.44±0.01	0.33±0.01
November		
Min	0.39	0.25
Max	0.46	0.28
χ±SD	0.37±0.01	0.26±0.01
December		
Min	0.45	0.34
Max	0.48	0.37
χ±SD	0.43±0.03	0.31±0.02
χ: Mean value SD: Standard deviation		

Table 4: The hydrocarbon analysis of Kafr altitude water in 2008 by FTIR method (#413.2/418.1).

Parameter	River Nile water*	Tap water*	Guidelines	Minimum detection limit
Aluminum (mg L^{-1})				0.023
Min	0.26	0.102	0.2	
Max	1.13	0. 200		
χ±SD	0.513±0.002	0.195±0.001		
Iron (mg L^{-1})				0.0004
Min	0.206	0.015	0.3	
Max	0.579	0.029		
χ±SD	0.335±0.002	0.069±0.001		
Manganese(mg L^{-1})				0.0001
Min	0.051	0.001	0.4	
Max	0.072	0.007		
χ±SD	0.065±0.001	0.004±0.001		
Sodium(mg L^{-1})				0.0001
Min	20.032	20.035	200	
Max	42.408	42.637		
χ±SD	29.541±0.200	28.464±0.130		
Potassium (mg L^{-1})				0.009
Min	4.123	4.409	-	
Max	6.861	6.87		
χ±SD	5.024±0.012	5.131±0.013		
Lead (µg L^{-1})				2.000
Min	UDL	UDL	10.00	
Max	4.56	3.435		
χ±SD	2.598±0.050	1.430±0.020		
Cadmium (µg L^{-1})				0.30
Min	UDL	UDL	3.00	
Max	0.089	0.032		
χ±SD	0.009±0.002	0.005±0.001		
Znic (mg L^{-1})				0.001
Min	0.005	0.006	3.0	
Max	0.329	0.224		
χ±SD	0.021±0.001	0.032±0.001		
Copper(mg L^{-1})				0.0005
Min	0.005	0.001	2.0	
Max	0.023	0.01		
χ±SD	0.007±0.002	0.004±0.001		
Chromium (µg L^{-1})				2.000
Min	0.29	0.27	50.00	
Max	2.987	2.184		
χ±SD	0.987±0.005	0.952±0.004		
Nickel (µg L^{-1})				1.30
Min	UDL	UDL	20.00	
Max	4.166	3.196		
χ±SD	1.689±0.013	1.011±0.002		
χ: Mean value *: n=3 SD: Standard deviation				

Table 5: Heavy metals measurements by using ICP-OES Varian simultaneous in River Nile and tap water at kafr altitude water plant.

14.45 mg L^{-1} as a maximum as shown in Table 4 and figure 16, bear in mind that the optimum level in the drinking water should be 2.94 mgL^{-1} according to Egyptian drinking water guideline [22].

Action plan

Declare a state of emergency by decreasing the number of suction pumps, insulating the water station inlet by oil sorbent, spreading the sorbent pads on the surface of the water into the slow mixing of the clarifiers or in the distribution zone, controlling the outlet of sand filters, carrying quality control of water every 2 hours, warning the other water plants and warning the people.

Water analysis

Tables 4 represented the levels of the hydrocarbon compounds before and after the accident from January till December. As shown in Table 4 the maximum levels of the hydrocarbons in Nile water are 14.45 mg L^{-1} in April and decreased up to 0.95 mg L^{-1} in June then returned back to its normal levels around 0.43 mg L^{-1} in July. Thanks for the sorbent the total hydrocarbons levels in drinking water not exceeded the drinking water Egyptian guidelines 2.94 mg L^{-1} and the mean was 2.03 mg L^{-1} in April (Table 4).

Heavy metals measurements were carried out by using ICP-OES

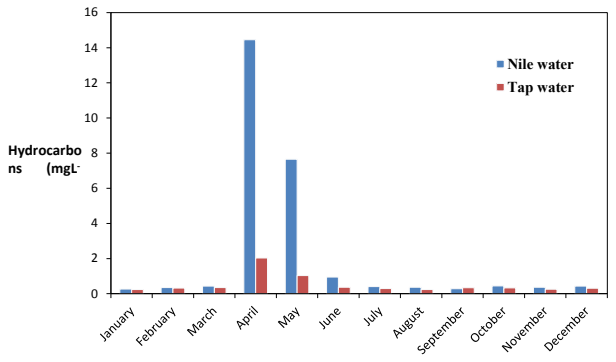

Figure 16: Mean values of the hydrocarbons analysis of Kafr altitude by (FTIR method #413.2/418.1) carried out in 2008 for Nile river and tap water.

Varian simultaneous. The levels of the heavy metals such as lead, cadmium, chromium and nickel increased as shown in Table 5 but still under the Egyptian guidelines for drinking water during the oil spill.

Conclusion

In the light of this incident and within the frame work of Cairo water company to apply a strategies axes of the Holding company of Drinking Water and Sanitation for continuous improvement of the target by raising the efficiency of drinking water companies and providing the training programs methodology as well as all the precautions necessary provided to face any petroleum infections which may adversely affect the efficiency of the plants and the pumps, the provided sorbent has a high adsorption capacity of 10:20 twice the size of the oil and easy plug the matter in water in few seconds.

Given the seriousness of the safety and efficiency of the water plant, which can lead to completely closed in the event of a petroleum oil spill in River Nile, Cairo Water Company acquires a rapid response by the personals and equipment of water plants to secure drinking water from the dangers of pollution and using limited amounts of sorbent without any closing of the water plants.

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References

1. Svanberg I (2006) Blacks slugs (Arion ater) as Grease: A case study of technical use of gastropods in pre-industrial Sweden. J Ethnobiol 26: 299-309.
2. George E, Shah RJ, Westbrook SR (2003) Fuels and lubricants handbook: Technology, properties, performance and testing 1: 560.
3. Gottlieb HE, Kotlyar V, Nudelman A (1997) NMR chemical shifts of common laboratory solvents as trace impurities. J Organic Chem 62: 7512-7515.
4. Forth HP, Mitchelmore CL, Morris JM, Lipton J (2017) Characterization of oil and water accommodated fractions used to conduct aquatic toxicity testing in support of the deepwater horizon oil spill natural resource damage assessment. Environ Toxicol Chem 36: 1450-1459.
5. Degrémont (1991) Water treatment hand book. (6thedn), 1.
6. Wang Z, Stout S (2010) Oil spill environmental forensics: Fingerprinting and Source Identification. Academic Press.
7. Reed M, Johansen Ø, Brandvik PJ, Daling P, Lewis A, et al. (1999) Oil Spill Modeling Towards the Close of the 20th Century: Overview of the State of the Art. Spill Sci Technol Bullet 5: 3-16.
8. MEDESS (2015) Marine pollution. Mediterranean decisions support system for marine.
9. Mishra Ak, Kumar GS (2015) Weathering of oil spill: modeling and analysis. Aquatic Procedia 4: 435-442.
10. Siguero-Guemes A (2010) Numerical modeling of the behavior of spillages of hirocarburos discharged into the sea. Ph.D. thesis. Universitat Politècnica de Catalunya.
11. Wang SD, Shen YM Zheng YH (2005) Tow-Dimensional Numerical Simulation for Transport and Fate of Oil Spills in Seas. Ocean Eng 32: 1556-1571.
12. Bautista H, Rahman KMM (2016) Review on the sundarbans delta oil spill: Effects on wildlife and habitats. Interna Res J 1: 93-96.
13. Heintz RA, Short JW, Rice SD (1999) Sensitivity of fish embryos to weathered crude oil: Part II. increased mortality of pink salmon (Oncorhynchus gorbuscha) embryos incubating downstream from weathered exxon valdez crude oil. Environ Toxicol Chem 18: 494-503.
14. Incardona JP, Carls MG, Teroaka H, Sloan CA, Collier TK, et al. (2005) aryl hydrocarbon receptor-independent toxicity of weathered crude oil during fish development. Environ Health Perspect 113: 1755-1762.
15. Carls MG, Rice SD, Hose JE (1999) Sensitivity of fish embryos to weathered crude oil: Part 1. Low-level exposure during incubation causes malformations, genetic damage and mortality in larval pacific herring (Clupea pallasi). Environ Toxicol Chem 18: 481-493.
16. Middlebrook AM, Murphy DM, Ahmadov R, Atlas EL, Bahreini R, et al. (2011) Air quality implications of the deep water horizon oil spill. Procee National Academy Sci 109: 20280-20285.
17. Tidwell LG, Allan SE, O'Connell SG, Hobbie KA, Smith BW (2015) Polycyclic aromatic hydrocarbon (PAH) and oxygenated pah (OPAH) air-water exchange during the deep water horizon oil spill. Environ Sci Technol 49: 141-149.
18. Lingering Lessons of the Exxon Valdez Oil Spill (2010).
19. Mazeikiene A, Svediene S (2011) Efficiency of petroleum products removal from aqueous mixtures with different sorbent materials. Environ Eng pp: 6013-6017.
20. Scardina P, Copeta G, Teragni P (2014) Environmental analysis: analysis of oil in water using the agilent cary 630 ftir, agilent technologies.
21. Eugene WR, Baird RB, Eaton AD, Clesceri LS (2012) Standard methods for the examination of water and wastewater. (22ndedn), American Public Health Association, American Water Association and Water Environmental Federation.
22. WCMRC (2015) Marine spill response on the west coast.