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A CASE STUDY OF RADIOACTIVE CONTAMINATION IN OIL PONDS AND ITS ENVIRONMENTAL RISKS

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This paper tried to highlight one of the most important sources of the environments pollutions which is produced water. Produced water always contains impurities and if present in sufficient concentrations,these impurities can adversely impact the environment. This work aims to study the level of radiation exposure generated from oil ponds for WAHA field as a case study and assessing the health risks for employers of the oil fields. Furthermore, evaluating the environmental impact of the local areas and the population growth is another approach. There is a lack of studies in this field and the interest in addressing the environmental impact, especially the densely populated areas. This will establish a baseline map of radioactive elements concentration levels in Libyan sites as well as determine radioactivity criteria and assessing of the dose and health risk resulting from radioactivity.

This study shows the seriousness of these radiations from the refining and production of oil companies to neighboring cities and could serve as important radiometric baseline data upon which future epidemiological studies and environmental monitoring initiatives.

1.0 Introduction

In this research, we conducted a field study of a water pond for water produced from one of the stations in the WAHA field,. The aim of this study is to measure the concentration of radionuclide activity ^{226}R, ^{232}Th, and ^{40}K in soil and sediment samples collected from (4) sites (4) Samples in the WAHA region - Libya to assess the radiation risks of TE-NORM residues from the oil and gas industry, and to estimate all indicators of Radiation risk, radium parabolic activity, absorbed dose, annual effective dose, annual gonadal overdose and cancer risk. The field of WAHA , located at length 21° 53' and latitude 29° 02' South East of the city of Benghazi with a distance of 550 km where is famous for the cultivation of palm and various agricultural crops due to its desert nature. It is a strategic and vital center for its natural resources represented by non-renewable natural resources (oil and gas), which represents the nerve and backbone of the Libyan economy, accounting for 25% of the production of this wealth, according to sources from the National Oil Corporation. This study was carried out in four locations include North Waha, South Waha North Defa and , South Defa station ponds.

2. Materials and Methods:

2.1. Sample Preparation And Measurements

four (4) Samples were collected from four locations as follows one Sample from each pond .Samples were collected from four ponds North Defa , South Defa, North Waha and South Waha station ponds. The Samples were collected by small brush made of soft plastic from 4 flat undistributed ground sites to avoid any parts of the original components of ground soil. The samples were collected from all sites during the period from 23 June 2023 to 24 June 2023. The collected samples were packed in PVC bags then transferred to the radiation laboratory . Each sample was dried in an oven at 105-110 ºC for approximately 24 h and sieved through a 2-mm mesh-sized sieve to remove any macro-impurities. They measured by high resolution gamma rays spectrometry system.

2.2. Gamma-Ray Spectra Measurements

A high purity vertical HPGe detector (p-type with a relative efficiency of 25% and peak to Compton ratio of 54:1) was used for measuring the γ-ray spectra of the samples. The energy resolution (FWHM) of the detector was 1.9 keV at the 1332 keV g-ray line of ^{60}Co source. The detector was coupled to a Canberra data acquisition system applying a Genie-2000.Analysis software, version 3.0, with many functions including peak area determination, background subtraction together with both g-ray energy and radionuclide identification. The HPGe detector was shielded with a lead cylinder of 10 cm thickness internally lined with 2 mm thick copper cylinder to absorb lead X-rays. The Sample containers were placed one at a time on the top of the detector (under the shield) for counting during an accumulation time of 80,000s.

3.0 Result and Discussion

3.1. Activity Concentration Of ^{238}u, ^{238}th And ^{40}k In Soil And Sediment Samples

The activity content of, **^{238}U, ^{232}Th** and **^{40}K** in the study area varies from minimum values of (18.99 Bq Kg^{-1} and 14.32 Bq Kg^{-1}) for **^{238}U, ^{232}Th** in North Defa respectively and (153.595 Bq Kg^{-1}) for **^{40}K** in South Defa pond, to maximum values (2936 Bq Kg^{-1}, 1512.64 Bq Kg^{-1}) for **^{238}U, ^{232}Th** in NorthDefa pond, and (492.06 Bq Kg^{-1}) for **^{40}K** in North Waha as shown in **Table (1) and Figure (1).** The mean activity concentration of **^{238}U** is above the global permissible limit of (35 Bq Kg^{-1}) in North Defa pond and South Defa pond), WAHA (ponds North and South), WAHA stations, were lower than the global average in DEFA stations . **^{232}Th** is above the world average of (30Bq-kg^{-1}) in North and South DEFA ponds and lower than in the others. **^{40}K** above global average, (400 Bq Kg^{-1}) in North Defa station and South Defa and below global average value for WAHA stations.

Table (1) *Natural radioactivity levels in soil and absorbed dose at different locations of WAHA area .*

	Activity concentration (Bq kg^{-1})						Absorbed dose rate (nGy h^{-1})	
	^{238}U		^{232}Th		^{40}K			
	Rang	**Mean**	**Rang**	**Mean**	**Rang**	**Mean**	**Rang**	
Present study	**18.99 - 2936**	**511.99**	**14.22 - 1512**	**225.49**	**152.5 – 492**	**311.18**	**30.97 – 2282.97**	**385.81**

3.2. Radium Equivalent Activity (Ra_{eq})

According to **(UNSCEAR, 2000)[5]**, Radium Equivalent Activity in (Bq/Kg) is estimated using the equation given below:

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \qquad \textbf{(1.0)}$$

Where, Ra_{eq} is a single parameter used to represent the radionuclide concentrations of ^{226}Ra, ^{232}Th and ^{40}K taking into account their respective radiation hazards.

The average value of the Ra_{eq} ranges from the minimum value (64.307 Bq Kg^{-1}) in WAHA field to maximum value (5123.08 Bq Kg^{-1}) in North Defa pond). **Table (2)** illustrates the calculated values of Ra_{eq}. The result of average values is higher than the upper limit of (370 Bq Kg $^{-1}$) in the North Defa pond and South Defa but lower than the dose limit in the other locations as shown in the **Figure (2).**

3.3. Annual Gonadal Equivalent Dose (AGED) µSv/ yr.

The gonads, the bone marrow and the bone surface cells are considered as organs of interest by **(UNSCEAR, 1988)**, because they are the most sensitive parts of human body to radiation. An increase in AGED has been known to affect the bone marrow and destroys the red blood cells which are then replaced by white blood cells. This situation results in a blood cancer (leukemia). AGED is calculated with given concentration of ^{226}Ra, ^{232}Th and ^{40}K (in Bq/Kg) using the relation[6]

$$AGED(\mu Sv/yr) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \qquad (2.0)$$

Where, C_{Ra}, C_{Th}, and C_K are the radioactivity concentration of ^{226}Ra, ^{232}Th and ^{40}K (in Bq/Kg) in soil samples respectively. The mean values of AGED are varies between (219.83 μSv/yr) in the location of WAHA field to (15492.38 μSv/yr) in the North Defa pond as shown in **Table (2)**, the result of values are higher than the world average value of (300 μSv/yr) and lower values in the North and South Waha cities. The **Figure (3)** represents the AGED level along

4.4. Activity Concentration Index (I_γ)

Another radiation hazard index called the representative level index, used to estimate the level of gamma radiation associated with different concentrations of some specific radionuclides, can be defined as follows [7].

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \qquad (3)$$

where C_{Ra} ,C_{Th} ,C_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bq \cdot Kg^{-1}$ were calculated for the samples under investigation to indicate different levels of external γ-radiation due to different combination of specific natural activities in other materials. This index can be used to estimate the level of γ-radiation hazard associated with the natural radionuclide in the materials. The average value activity concentration index determined were (34.90) as maximum in North Defa pond to (0.49) as minimum in South Waha as shown in **Table (2)** and **Figure (4).** The result of activity concentration mean value was found excessed unity limit of 1 in North and South Defa ponds , North Waha, but not excess unity in South Waha pond, An increase in the representative gamma index greater than the universal standard of unity may results in radiation risk leading to the deformation of human cells thereby causing cancer **[8]**.

3.5. Annual Effective Dose Equivalent (AEDE) (μSv/y)

The annual effective dose equivalent received outdoor by a person is calculated from the absorbed dose rate by applying dose conversion factor of 0.7 Sv/Gy. Taking into consideration that people on average, spent 20% of their time outdoors, occupancy factor for outdoor and indoor is 0.2 (5/24) and 0.8 (19/24) respectively[9].

$$D_{Outdoor}(\mu Sv\ yr^{-1}) = [D_r(nGy\ hr^{-1} \times 8760hy^{-1} \times 0.2 \times 0.7Sv\ Gy^{-1}] \times 10^{-3} \quad (4)$$

$$D_{Indoor}(\mu Sv\ yr^{-1}) = [D_r(nGy\ hr^{-1} \times 8760hy^{-1} \times 0.8 \times 0.7Sv\ Gy^{-1}] \times 10^{-3} \quad (5)$$

The absorbed dose rate D (nGh/h) calculated by the following equation.

$$D(nGy/h) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K \quad (6)$$

Where **D** is the dose rate at 1 m above the ground, and A_{Ra}, A_{Th}, and A_K are the activity concentrations (Bq kg^{-1}) of ^{238}U, ^{232}Th, and ^{40}K, respectively, in the soil sample**.** The average annual outdoor effective dose **Table (2)** column 6 ranged from (2799.97µSv/y) in the North Defa pond to (37.98µSv/y) in the South Waha. However, the mean annual effective dose calculated in this study was higher than the world average value of (70 µSv/y) except North and South WAHA ponds**.** As shown in the **Figure (5)**. The values of the annual effective dose equivalent of the indoor are ranged from (11199 µSv/y) in the Naorth Defa pond to (151.93µSv/y) in the South Waha city as illustrate in **Table (3)** and **Figure (6)** the mean value of North Defa pond and South Defa pond are excessed the upper limit of AEDE is value (450µSv/y).while the other locations are below the upper limit of AEDE. These indices measure the risk of stochastic and deterministic effects in the irradiated individual**.**

4.6. External Life Cancer Risk (ELCR):

An increase in the ELCR causes a proportionate increase in the rate at which an individual can get cancer of the breast, prostate or even blood.

Excess lifetime cancer risk (ELCR) is given [10] as

$$\boldsymbol{ELCR = AEDE \times DL \times RF} \quad (7.0)$$

The values of the external life cancer risk is ranges from 48.99 in the North Defa pond to (0.67) in the South Defa as illustrate in the **Table (2)**, It is clearly the value excess the world average value of (0.29 x10^{-3}), the profile of (ELCR) in study area of WAHA field as shown in **Figure (7)**. An increase in the ELCR causes a proportionate increase in the rate at which an individual can get cancer of the breast prostate or even blood[11] **.**

4.7. External And Internal Hazard Index

The external hazard index (H_{ex}) defined by the equation below,

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \qquad (8.0)$$

Where, C_{Ra}, C_{Th} and C_K are the radioactivity concentration in Bq/kg of ^{232}Th, ^{238}U and ^{40}K. The value of this index must be less than unity for the radiation hazard to be insignificant. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} (370 Bq/Kg), The internal hazard index is given as[12].

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \qquad (9)$$

H_{in} should be less than unity for the radiation hazard to be insignificant. Internal exposure to radon and its daughter products are very hazardous and can lead to respiratory diseases like asthma and cancer. As shown in the **Table (2)** the mean average of External hazard index (H_{ex}) were ranges from (13.85) in North Defa pond to (0.17) in WAHA field as illustrate in **Figure (8)** the result mean value is excess the dose limit of unity in North and South Defa ponds . but lower than the limit of unity in the other locations. It's important to know if the average size of H_{ex} is greater than 0.3, it will increase the risk up to 30%, therefore people , who are living in that area, must comply with safety principle

The mean values of internal hazard index (H_{in}) were ranges from (21.77) in North Defa pond to (0.23) in WAHA field. The average value is higher than dose limit of unity in North and South Defa ponds but lower than in other locations as shown in **Table (2)** and **Figure (9).** The quantity of internal exposure to radon and its short – lived decay products is given by internal hazard index (H_{in}). The value of H_{in} must be less than unity to have insignificant hazardous effect of radon and its short – lived decay products to the respiratory organs .[13] .

Table (2) *Average level of radioactivity contents (Bq/Kg) in study area at WAHA field*

Location	**$^{226}R_a$**	**$^{228}R_a$ (AC)**	**^{40}K**
North Defa	2936	1512.64	305.79
South Defa	599.36	165.31	153.59
North Waha	303.87	23.97	184.28

South Waha	49.27	16.96	331.53
Max	**2936**	**1512**	**492.06**
Min	**18.99**	**14.32**	**153.59**
Average	**511.995**	**225.49**	**311.18**
World average	**35**	**30**	**400**

Table (3) *values of radium equivalent (Ra_{eq}), annual gondal equivalent dose (AGED), gamma index (I_γ), absorbed dose rate (D), annual effective dose equivalent outdoor, annual effective dose equivalent indoor, external life cancer risk, external hazard index and internal hazard index for all study area at* **WAHA field.**

Location	$_{eq}$Ra (Bq/Kg)	AGED (μSv/y)	$_{r\gamma}$I	EDEA Outdoor (y/vSμ)	AEDE Indoor μ)(Sv/y	ELCR	$_{ex}$H	$_{ni}$H
North Defa Pond	5123.08	15492.38	34.90	2799.97	11199.92	48.99	13.85	21.77
South Defa Pond	843.08	2591.26	5.75	1879.83	1879.83	8.22	2.29	3.91
North Waha Pond	352.33	1097	2.39	797.67	797.67	3.49	0.952	1.77
South Waha Pond	99.05	327.22	0.72	230.22	230.22	1.00	0.27	0.40
Min.	64.307	219.83	0.49	151.93	151.93	0.67	0.17	0.23
Max.	5123.08	15492.38	34.90	11199.92	11199.92	48.99	13.85	21.77
Mean study area	858.468	2622.45	5.876	1892.72	1892.72	8.27	2.32	3.703
Max. Permissible limit	370	300	1	70	450	0.029×10^{-3}	≥ 1	≥ 1

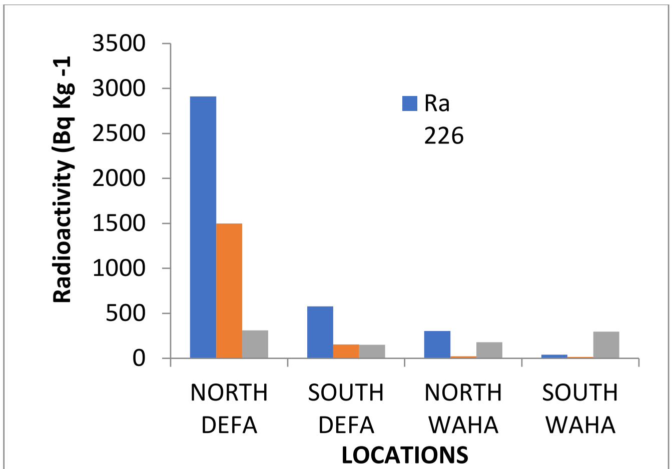

Fig. (1) Average level of the activity .concentration values of ^{238}U, ^{232}Th and ^{40}K

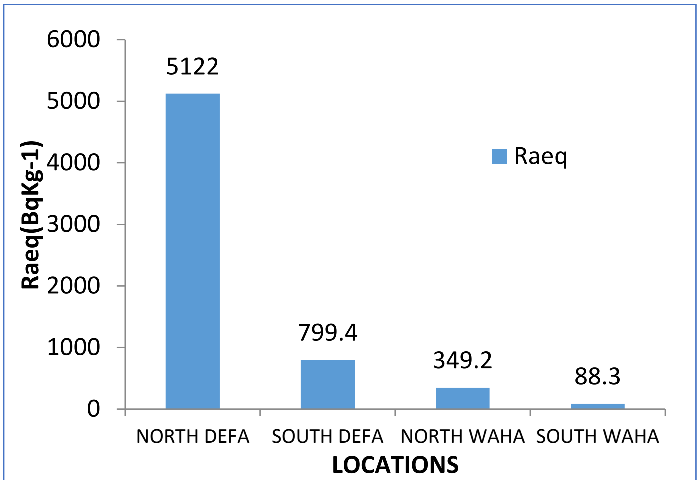

Fig. (2) The Ra_{eq} ($Bqkg^{-1}$) le

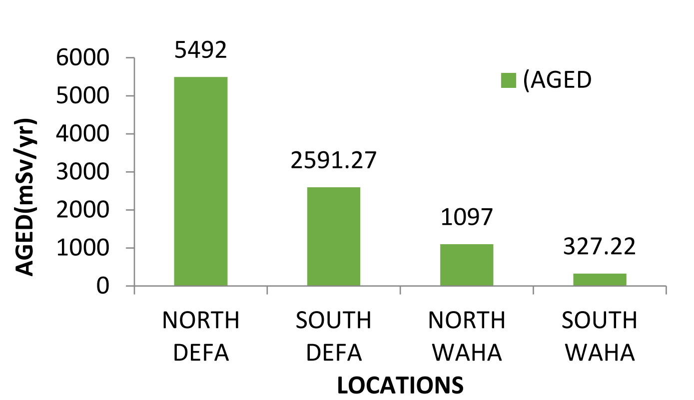

Fig. (3) The AGED (mSv/yr) level along study area

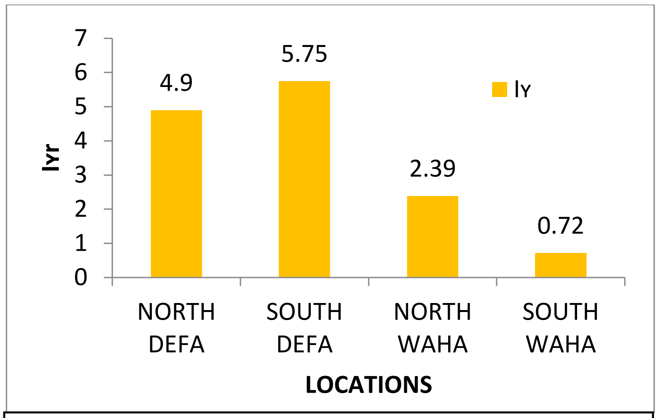

Fig. (4) The representative gamma index (I_γ) levels along study

area

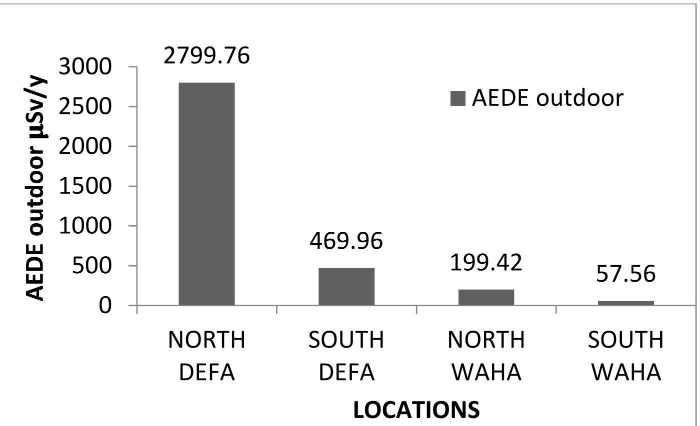

Fig. (5) *(AEDE) for outdoor (µSv/y) levels* along study area

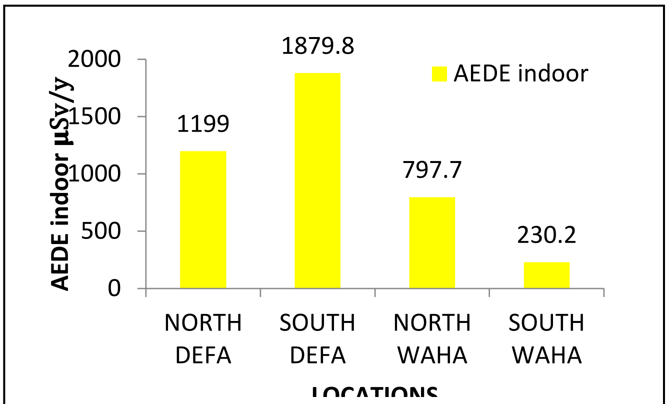

Fig. (6) *(AEDE) for Indoor (µSv/y) levels* along study area

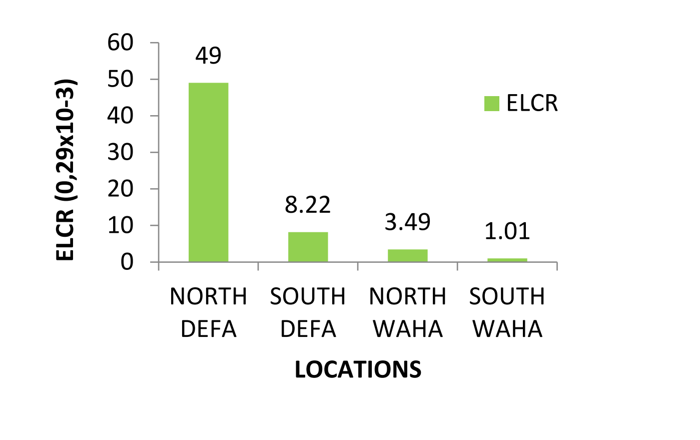

Fig. *(7) External life cancer risk levels* along study area

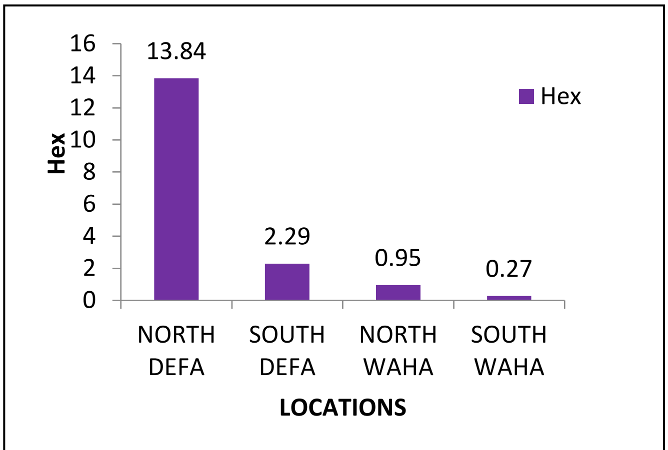

Fig. *(8) External hazard index levels* along study area

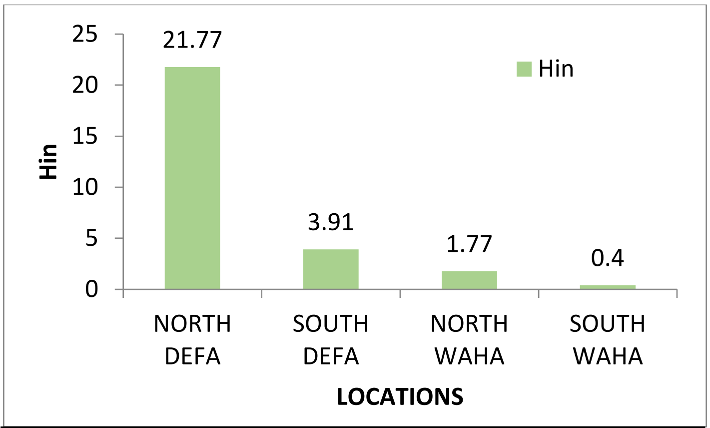

Fig. *(9) Internal hazard index levels along the study sites.*

4.Conclusions

- The high radiation values in WAHA field compared to the global average rate and environment protection organization which endangers people and animals through inhalation and ingestion which lead to the spread of diseases such as cancer miscarriage and skin diseases.
- Uncontrolled work activities involving NORM and TENORM can lead to unwanted exposure and dispersal posing a risk to human health and the environment.
- Harmful radiation effects were posed to the population who live in the study area. Higher values of ^{226}Ra, ^{228}Ra and ^{40}K concentrations and radiation hazard levels are observed in North and South Defa ponds, North and South Waha ponds base samples, notably, this area contains production .

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