Annual Technical report of round 2023-2024

Evaluation of Radioactivity in Dubaydib well field Disi Raw Water, Combined well field, and Blended

Water (Dabuk, and Abu Alanda)

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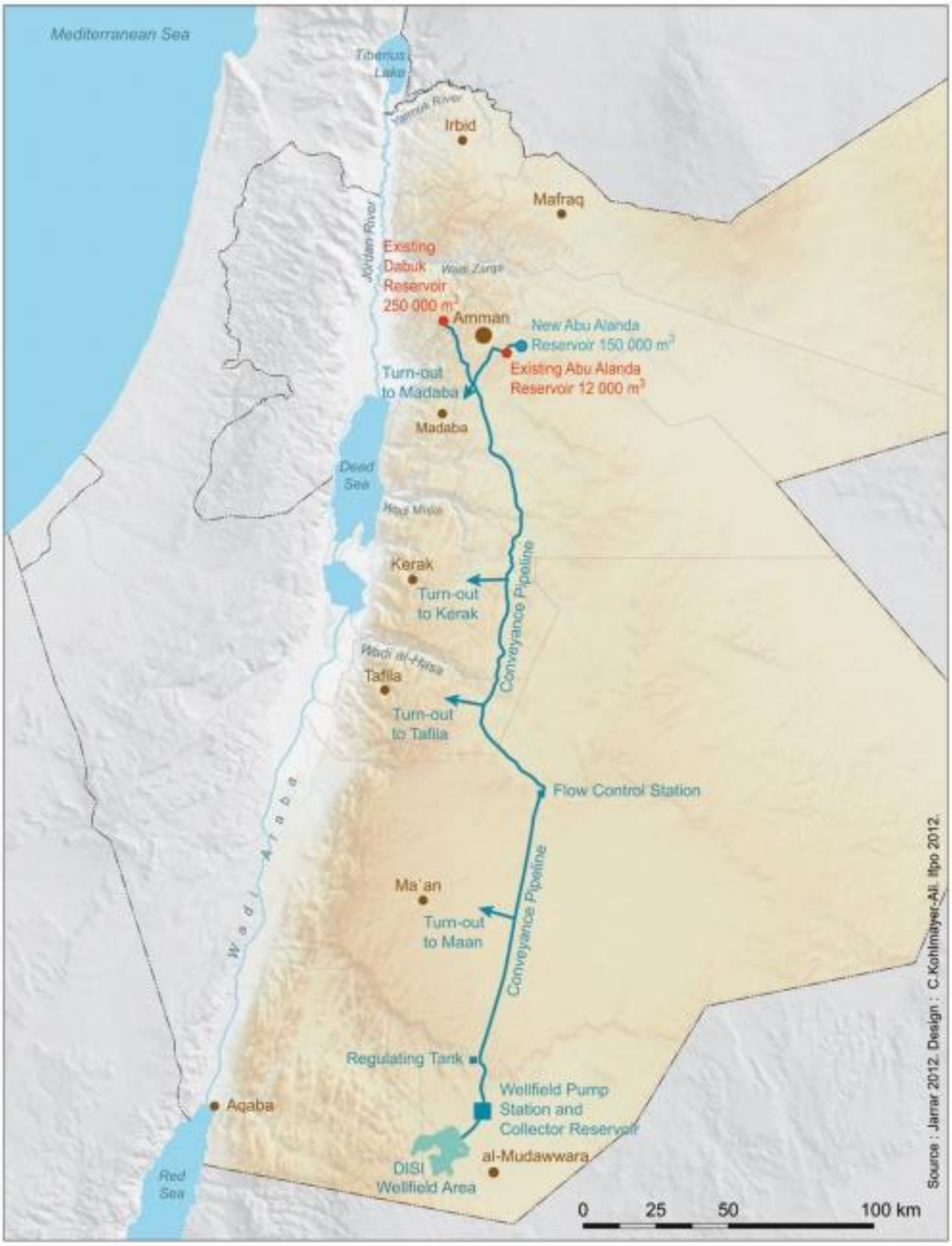

Disi Water Conveyance Project

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Glossary and abbreviations

MWI: Ministry of Water and Irrigation.

WAJ: Water Authority of Jordan.
GL: guidance level for radionuclide in drinking water.
IDC: Individual dose criterion, equal to 0.5 mSv/y (JS286).
DC: Dose Coefficient for ingestion by adults (mSv/Bq).
Q: annual ingested volume of drinking water, assumed to be 730 liters / year.
DAOM: Disi Amman Operation and Maintenance
TED: Total annual Equivalent Dose (mSv/y)
CRa-226, CRa-228, CPb-210: Concentration of Radium-226, Radium-228 and Lead-210 respectively (Bq/l)
LSC:Liquid Scintillation Counter
ESMP#2: Environmental and Social Management Plan #2.
BH: Boreholes.
BA: Zai water treatment plant
BB: Zara water treatment plant
SA: Booster dabuk outlet
SB: Marghab outlet
ERA: Environmental Resource Associates.
NIST: National institute of Standards and technology.
QSM: Quality System Manual.
RDL: Radioactive Dose Limit.
UNSCEAR: The United Nations Scientific Committee on the Effects of Atomic Radiation
Aquifer: Formations, or part of formation that is water bearing.
JS286/2015: Jordanian Drinking Water Standard 286/2015.
mSv/y: Unit of Annual Effective Dose (mille Sievert /y).
Bq/l: Becquerel per liter
HPGE: High purity Germanium Detector
FWHM: Full width of half maximum.
OECD: the Organization for Economic Co-operation and Development
Ra_{eq}:Radium equivalent activity (Bq/kg),

AED: Annual Equivalent Dose

1. Introduction

Ministry of Water and Irrigation required monitoring regime under this ESMP 2, for the Disi Project is based on the principles of the Jordanian Drinking Water Standards 286:2008 – 5th Edition (JS 286), the WHO Guidelines for Drinking-Water Quality, information provided by MWI to Lenders and the requirements under the Sovereign Loans. The water quality and flow monitoring procedure and the blending requirements are specifically targeted at ensuring that the water supply from the Disi Project is compliant with JS 286 by the time that it reaches drinking water users.

The Disi Water Conveyance Project is a major infrastructure project in Jordan that aims to address the country's chronic water shortages. Jordan is one of the most water-scarce countries in the world, with limited natural water resources and a rapidly growing population.in addition to climate change problem, in which affect the water resources either.

The Disi project involves pumping water from the Disi aquifer, located in the southern part of Jordan near the Saudi Arabian border, to the capital city of Amman, which is located about 325 kilometers away.

The project consists of a pipeline that runs from the Disi area to Amman, with a total length of approximately 325 kilometers. The pipeline has a capacity of 100 million cubic meters per year, which is equivalent to about 300,000 cubic meters per day. The water is pumped from wells located in the Disi area, which are about 600 meters deep in average, and is transported to Amman through a system of pumps and pipelines

While the Disi project has helped to address some of Jordan's water shortages, it is important to note that it is a temporary solution that will not solve the underlying water scarcity issues in the country. Jordan will need to continue to explore and develop sustainable water resources to ensure that its population has access to safe and reliable water in the long term.

The Disi aquifer has been known to contain naturally occurring radionuclides such as radium and uranium.

The Jordanian Ministry of Water and Irrigation has conducted several studies to monitor the radioactive quality of groundwater in the Disi aquifer. However, it is important to note that continued monitoring of the quality of groundwater in the Disi aquifer is essential
, starting in 2023a new assessment for Disi aquifer has been started done upon agreement with AFD, BRGM, MWI and WAJ.

2. Responsibility of MWI/WAJ

This report is prepared in accordance with MWI/WAJ's obligations, stipulated under the Environmental and Social Management Plan #2 (ESMP2), to demonstrate the compliance with requirements of section 3.2.2 of ESMP2. The purpose of this report is to assess the radioactivity level of groundwater in the Disi well field (BH), Combined well field (CO), Blending water from Zai and Zara water treatment plants (BA and BB),and blended water from Dabuk network which is Boster Dabuk and Abu Alanda network which is Al Margab (SA and SB respectively)

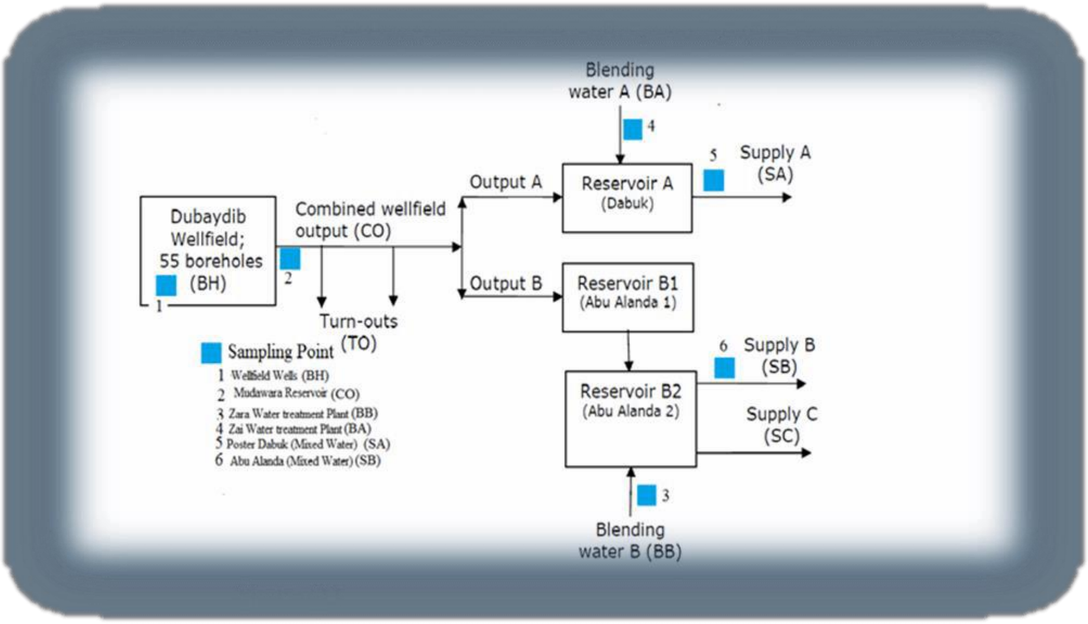


Fig (1) schematic diagram of the transition stages from Disi wells field to network and sampling points.

With reference to Monitoring Phase 3.2 of Part 2 of ESMP2:

"3.2.2 Operational Phase
MWI is required to prepare a consolidated report on water quality (for radioactivity and other related parameters) on an annual basis. The report shall be submitted to the Lenders and the Project Company. As a minimum during commercial operation, MWI is required to undertake and report on the following sampling regime and activities:

• **Sample all operating boreholes (BH) and the blending water (BA and BB)** at a minimum frequency of every 3 months for the first 12 months of operation, and every two years thereafter, to determine the blending requirements for providing drinking water according to JS

286, and to assess any seasonal variations in radionuclide concentrations. Sampling must include the following :

- **Total alpha and total beta activity**
- **Activities for radionuclides including radium (Ra-226 and Ra-228)**

- **Sample the combined flow (CO) and the blended water (SA, SB and SC**), supplied to the distribution network at a minimum frequency of every month for the first two years of operation and quarterly thereafter except as otherwise agreed between MWI and the Lenders, to determine compliance with JS 286. Sampling must include the following:

- **Total alpha and total beta activity**
- **Activities for radionuclides including radium (Ra-226 and Ra-228)**

- **Sample the combined flow (CO),** at a minimum frequency of every quarter during the first year of operation and annually thereafter for the following parameters :

- **Activities for radon (Rn-222) and lead (Pb-210) radionuclides**

3. Methodology

3.1 Sample Collection and Preparation

Twenty liters (20L) of water from each operating boreholes (55 wells), Blending water point (BA), Combined flow (CO), and Blended water points (SA and SB) were collected at the same needed frequency.

Each unfiltered sample (20 liters) was used to provide three sub-samples: 8 liters for Ra^{228}, and Ra^{226}, 1 liter for Pb^{210} analysis and 1 liter for gross alpha and gross beta analysis. The remaining volume was retained to facilitate repeat analysis if required and QC needs.

Samples for Ra^{226}, Ra^{228} and Pb^{210} analysis were collected in virgin polyethylene containers and acidified to a pH of<2 in the laboratory using 69% HNO3.
Samples for gross alpha and gross beta analysis were collected in 1Lpolyethylene and acidified to a pH of<2 in the laboratory using 69% HNO3 ,this method has been modified in2023 to be as per listed in the standard method 24th edition Each sample was allowed to stand for at least 24 hours prior to chemical analysis to ensure that all acid-soluble substances entered solution.
For the BA, CO, SA&SB a sampler has been installed and a monthly samples were collected in a 20L polyethylene container acidified prior replacement of the filled ones and analyzed as alpha, beta, Ra^{226} &Ra^{228} to represent the monthly pumping radioactive water quality.

3.2 Measurement of sample

3.2.1 Determination of gross alpha and gross beta activity

Gross alpha and gross beta analysis were performed via evaporative enrichment, method has been modified in 2023 to be based on the 100ml of acidified sample till dryness then re dissolve the sample with 8 ml of 0.1 M of HNO3, The acidified sample is transferred quantitatively to around 10 ml and to the Packard counting vial, and then10 ml of Ultima Gold LLT (liquid scintillation cocktail) is added. The vial is sealed and counted 5 times for 30 minutes each time by Liquid Scintillation Analyzer model **3110**.& Liquid Scintillation Analyzer model **4910**(a new LSC purchased and installed in 2023)

Liquid scintillation counting (LSC) using a Canberra Packard liquid scintillation analyzer equipped with alpha discriminator (pulse decay analysis). This methodology was modified from standard method for the Examination of water and waste water 24th edition, and the manufacturer instruction via the instrument handling, and has been validated for the determination of gross alpha and beta radioactivity by laboratory quality control schemes and accredited to ISO 17025:2017 in the WAJ/MWI laboratories. The quoted lower reported value (0.20 Bq/l and 0.50 Bq/l, respectively) and combined uncertainty for these methodologies (7.45% and 7.45%, respectively) for 3110,and The quoted lower reported value for 4910 (0.20 Bq/l,0.60 Bq/l respectively)

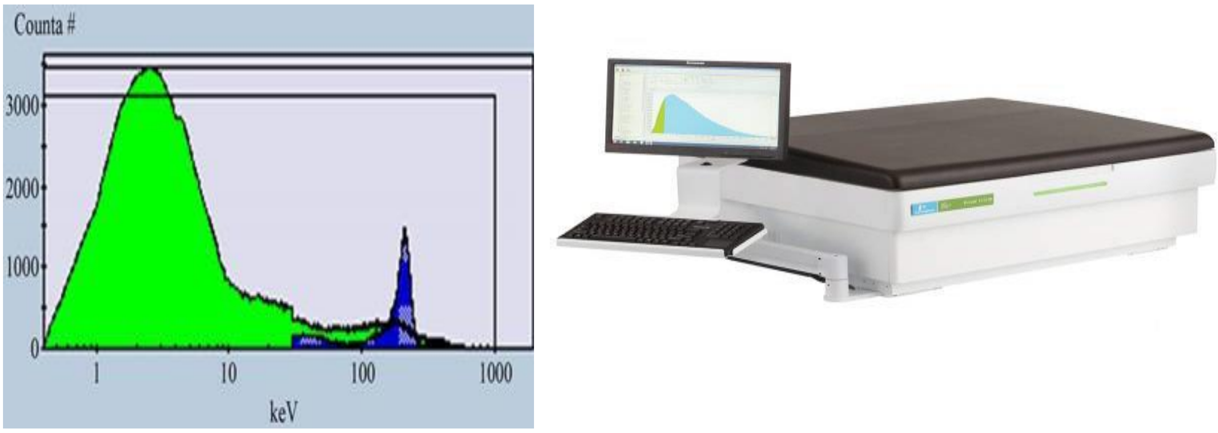


Fig (2) A Canberra Packard 3110TR liquid scintillation analyzer and spectrum of gross Alpha and Beta.

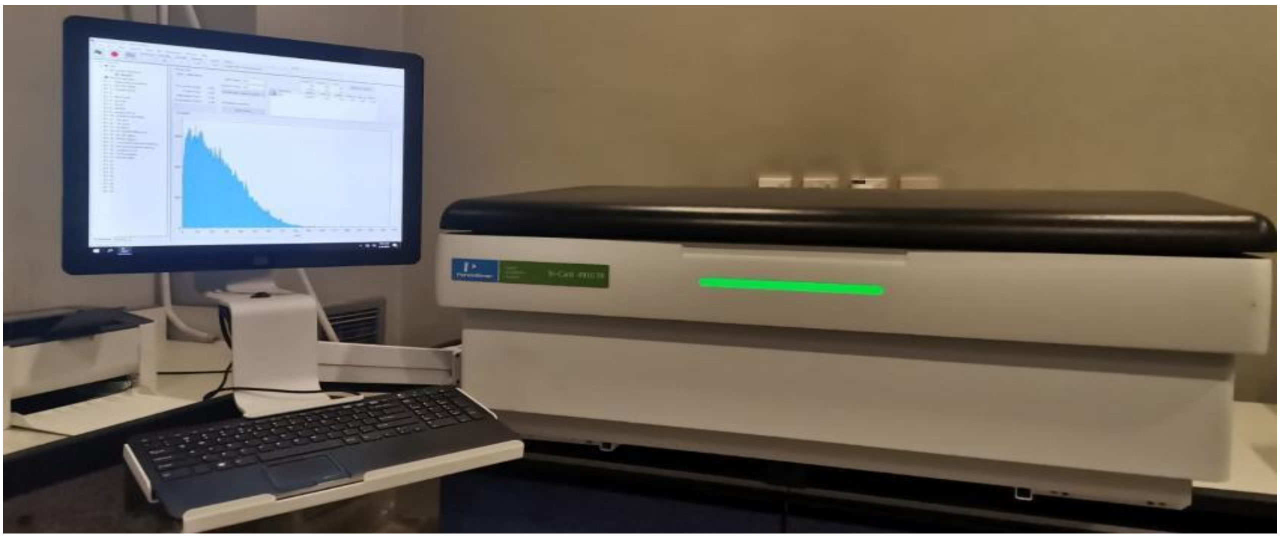


Fig (2) B Canberra Packard 4910 TR liquid scintillation analyzer and spectrum of gross Alpha and Beta

3.2.2 Determination of Ra^{226} and Ra^{228}

Two Gamma Spectrometers are used, equipped with extended range Low Level High Purity Germanium; the old one is installed in 2010 BE 5030 detector (HPGE) with 104mm End cap and 0.3 mm carbon window, 50% efficiency and high resolution FWHM 2.2 at 1332 Kev. The Detector is connected to standard extra processor DSA 1000 desktop inspector electronics

The newest one installed and operated in 2018 GEM-C5970-RB-ST with 70mm end cap diameter carbon window. With a resolution of 2.08 at1330kev. The Detector is connected to standard extra processor DSA 1000 desktop inspector electronics

The detectors are surrounded with 15 cm thick lead shield in order to reduce the background and 0.5 cm copper layer to attenuate X-rays emitted by lead shield. The energy calibration of the spectrum is done using a multi gamma radioactive standard source prepared in the same geometry as the samples to be analyzed (Eckert&Ziegler isotope Products) with total activity of 37kbq. The efficiency calibration for both spectrometers is done by using Standard Ra228 and Ra226 from Ekert&Zighler and Isotope Product Laboratories (IPL) respectively, another source of standards from Environmental Resource Associates (ERA) for Ra226 isotope is used as a Calibration Verification Standards which are prepared by dilution. While different Eckert and Ziegler standard Batch is used for Ra228 as Calibration verification Standards are NIST traceable.

An 8-litre acidified sample was evaporated to a final volume of 1 liter. Transferred and closed and stored for 1 month to allow secular equilibration of Ra^{226} with ingrowing. The water samples should be tightly sealed to stop radon (Rn^{222}) escaping from Marinelli beakers. The methodology relies on measuring the gamma energy of Ra^{228} via Ac^{228} at 911 Kev. And gamma energy of Ra^{226} via Bi^{214} at 609.31 Kev .for Canberra instrument This method provides a low lower reported value (0.13 Bq/l and 0.12 Bq/l respectively) and is validated and accredited to ISO 17025:2017 in the WAJ/MWI laboratories for the determination of Ra^{228} and Ra^{226} in drinking water with a combined uncertainty of (7.17% and 9.8% respectively).while a and lower reported value (0.15 Bq/l ,0.10Bq/l respectively)| a combined uncertainty of(6.43 % and11.07% respectively) for Ortec.

Fig.3 Gamma spectrometry (HPGE) Canberra & Ortec

3.2.3 Determination of Lead-210

One liter acidified sample enriched to 50 ml, after preparing 10ml cation exchange column , sample is passed through .Lead is separated from other elements on an Eichrom Pb Resin Column. The purified lead fraction is collected and sealed for 30 days to allow completion of secular equilibrium with Bi210 ingrowths, then sample is counted by Liquid Scintillation Analyzer (Quantulus 1220).[Ref. 7] (ultra low background)

The method of this analysis is based on the method suggested by Eichrom Technologies, Inc. (OTW01 Rev. 1.8).

This method provides a low lower reported value (0.02 Bq/l) and is validated to ISO 17025:2017 in the WAJ/MWI laboratories for the determination of Pb210 in drinking water.

3.2.3 Determination of Radon-222 Gas

Radon gas is performed via DURRIDGE RAD7 which has a measurement chamber containing an electrostatic field. When radon atoms enter the RAD7 and decay Po^{218} (half-life 3.05 minutes) deposited onto the surface of the RAD7's Canberra Alpha detector .After about 4.3 half-lives or 13 minutes, the RAD7 count rate reaches 95% of its equilibrium value.RAD7 also detect the decay of Po^{214}, a later daughter of radon which takes about three hours to reach equilibrium with radon in the measurement chamber. Using the default settings, The RAD7 will being recording measurements with increased precision after three hours by counting both Po^{218} and Po^{214} decays.

This makes the RAD7 uniquely suited for Radon testing. It is built to withstand demanding use in the field.

This method provides a low detection limit 1 pCi/L (40 Bq/m3) .

In the WAJ/MWI laboratories for the determination of Rn222 in drinking water.

Rn222is also analyzed using liquid scintillation counters with a precise technique of sampling with a special type of cocktail -Opti flour(for gases) taking into consideration correction of time from sampling up to counting time .

3.3 Quality control:

The laboratory has been internationally accredited to ISO 17025 by UKAS since 2005. Accreditation continued through Accreditation Unit of the Jordanian Accreditation and Standardization System (JAS-AU) The department operates in compliance with relevant QA/QC requirements and continually participates in International Proficiency Testing (PT) programs, generally annually, as conducted by external proficiency testing providers such as IAEA, ERA and Aqua check.

Throughout sample handling, preparation and measurement , all the requirement of the ISO 17025:2017 were followed that includes quality assurance and quality control protocols according to the laboratory Quality System Manual (QSM) and supporting quality documents. The quality control results of the blank, matrix spike, and replicate analysis can be furnished upon request.

4. WATER RADIOACTIVITY

Methodologies for the calculation of an individual's annual radiological effective committed dose from the consumption of naturally occurring and man-made radionuclides via the drinking water pathway, and/or the concentration of a specific radionuclide in drinking water that would result in a dose that exceeds a specific individual dose criterion, are laid out in the WHO and Jordanian standards for drinking water quality (WHO 1993, 2004, 2011).
In these calculations (Table 1) Jordanian regulations (JS 286/2015) require the use of an adult drinking water consumption rate of 730 L/y, an individual dose criterion of 0.5 mSv/y and the use of dose coefficients listed in Table 1 (as derived from WHO 1993, 2008, 2011). When more than one of these radionuclides are present, the resulting AED represents a summation of AED equivalents from each of the radioelements present

Based on data from previous studies of groundwater from the Ram aquifer, radionuclides that are the highest contributors to radiological dose through the consumption of Disi water directly at the well head are Ra226, and Ra228 whereas concentration of lead Pb210 was equal or less than detection limit (0.02Bq/l) for most of the wells which means that it has no contribution on Annual Effective Dose (AED).

Accordingly the Total Annual Effective Dose is calculated by the following equation:

$$AED = [C_{Ra\text{-}226} * DC_{Ra\text{-}226} * Q] + [C_{Ra\text{-}228} * DC_{Ra\text{-}228} * Q] \quad \text{eq. (1)}$$

Indicative levels of radionuclides in drinking water are presented in Table 1. Assuming that each of the mentioned nuclides is the only source of radioactivity in water, that is, we calculated the concentration of the specific nuclide if it was the only source of radioactivity in drinking water, and it alone would constitute the entire radioactive dose.
The following equation calculated the indicative levels of radionuclides in drinking water:

$$GL = AED / (DC * Q) \quad \text{eq. (2)}$$

Radionuclide	Dose Coefficient (mSv/Bq) (DC)	Guidance level (Bq/litre) (GL)
Radium-226	$2.8X10^{-4}$	2.44
Radium-228	$6.9X10^{-4}$	0.99

Table (1) Guidance levels for the radionuclides contributed in AED.

5. Results and interpretation of data:

According to ESMP No. 2, three major categories should be covered by the tour which are the radioactivity of 55 wells which were covered in the first part, the radioactivity at delivery points (mixing points), which were covered in the second part and the third category is the activity radioactivity in the combined wellfield, which was covered in the third part of this section

The following results and data will discuss the radioactive quality of water in the three parts of the project mentioned above and the safety of the water provided to the population of Jordan.

5.1 PART ONE: Radioactivity in the Boreholes (BH)

Sampling for the current two years round began at the beginning of 2023 and continued during 2024 Regular field visits were carried out to the Disi project every three months to cover 6-8 wells depending on several factors in the field.

All results required for boreholes according to ESMP No. 2 for the round 2023-2024 of gross alpha, gross beta, Ra^{226} and Ra^{228} in water from all Disi wellfield for the samples wells (55) are shown in Table No. 1 in Appendix No. 1

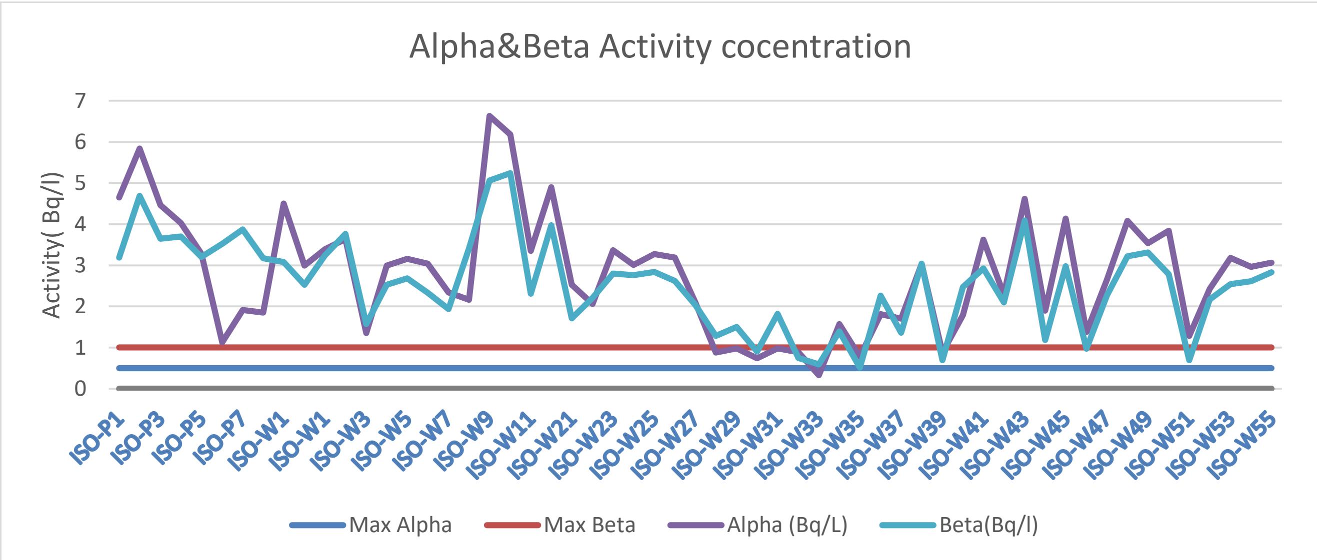


Fig.4 Disi wells against Alpha and Beta concentration for each of them, note that Max Alpha &Beta refers to JS(J286/20215) which is 0.50Bq/l for Alpha &1.0Bq/l for Beta.

as per required in ESMP No. 2,and according to the Jordanian Standard (J286/2015) as well, it's a must to determine Ra^{226} and Ra^{228} values in order to calculate the AED ,for the samples that's exceeds the limits for gross alpha and beta

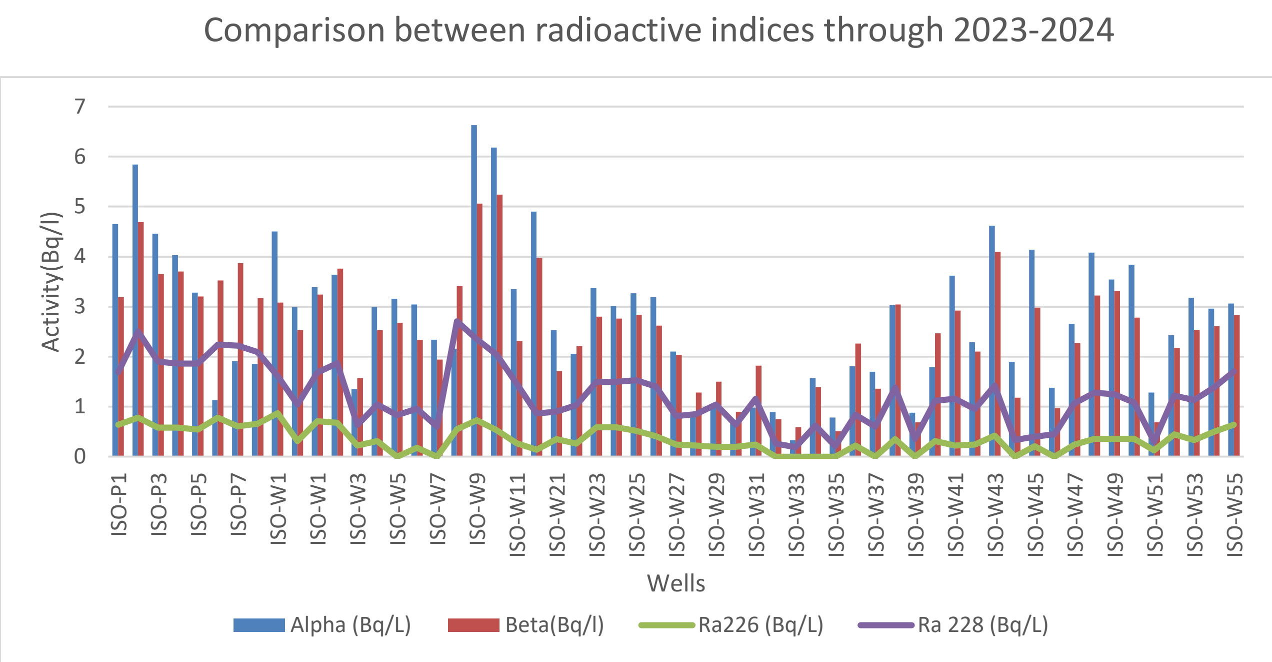


Fig.5 shows the relation between alpha, beta with Ra^{226}&Ra^{228}, it's obviously noticed that the presence of alpha and beta will surely be a first indication if there is Radium in the wells, on the other hand Ra^{228}activity is more than the Ra^{226} activity for the same well

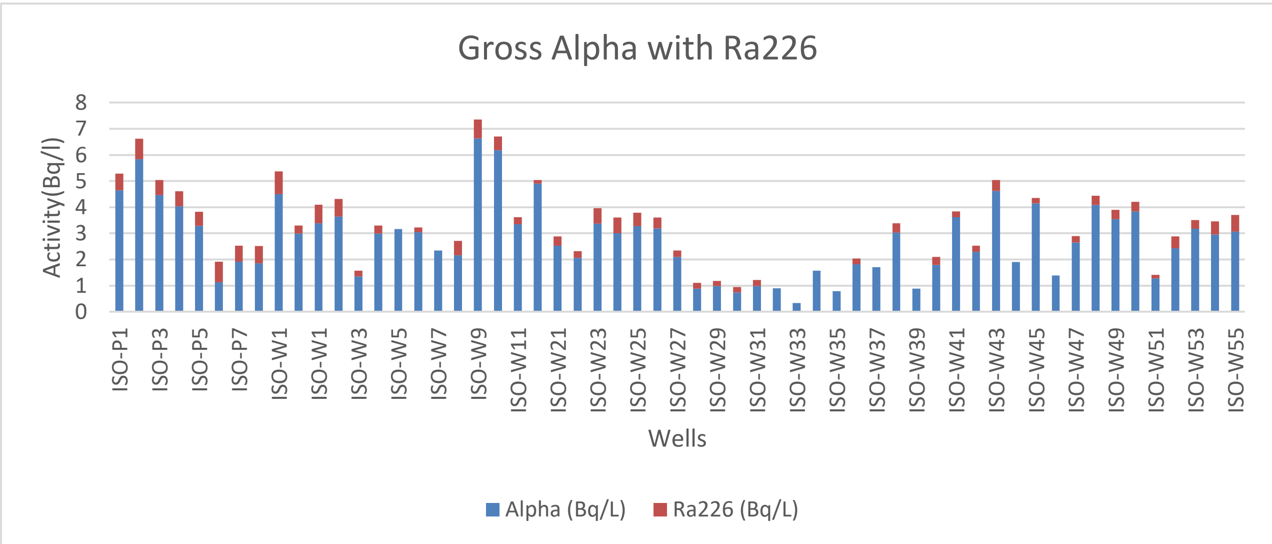


Fig.6 shows the relation between the gross alpha and Ra^{226}, in which presence of alpha is the first indication for Ra^{226} presence.

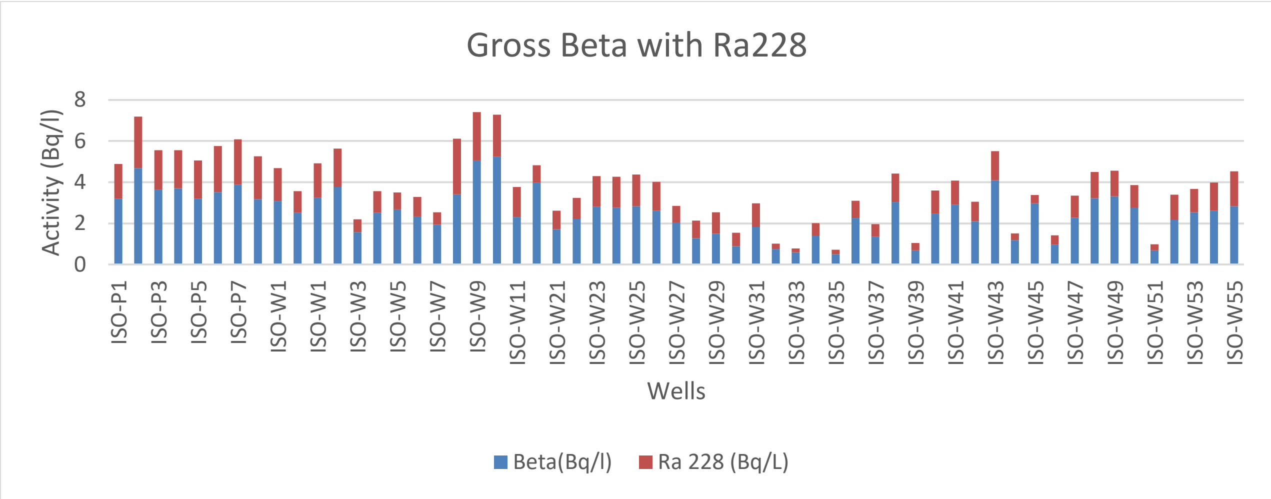


Fig.7 shows the relation between the gross beta and Ra^{228}, in which presence of beta is is the first indication for Ra^{228} presence.

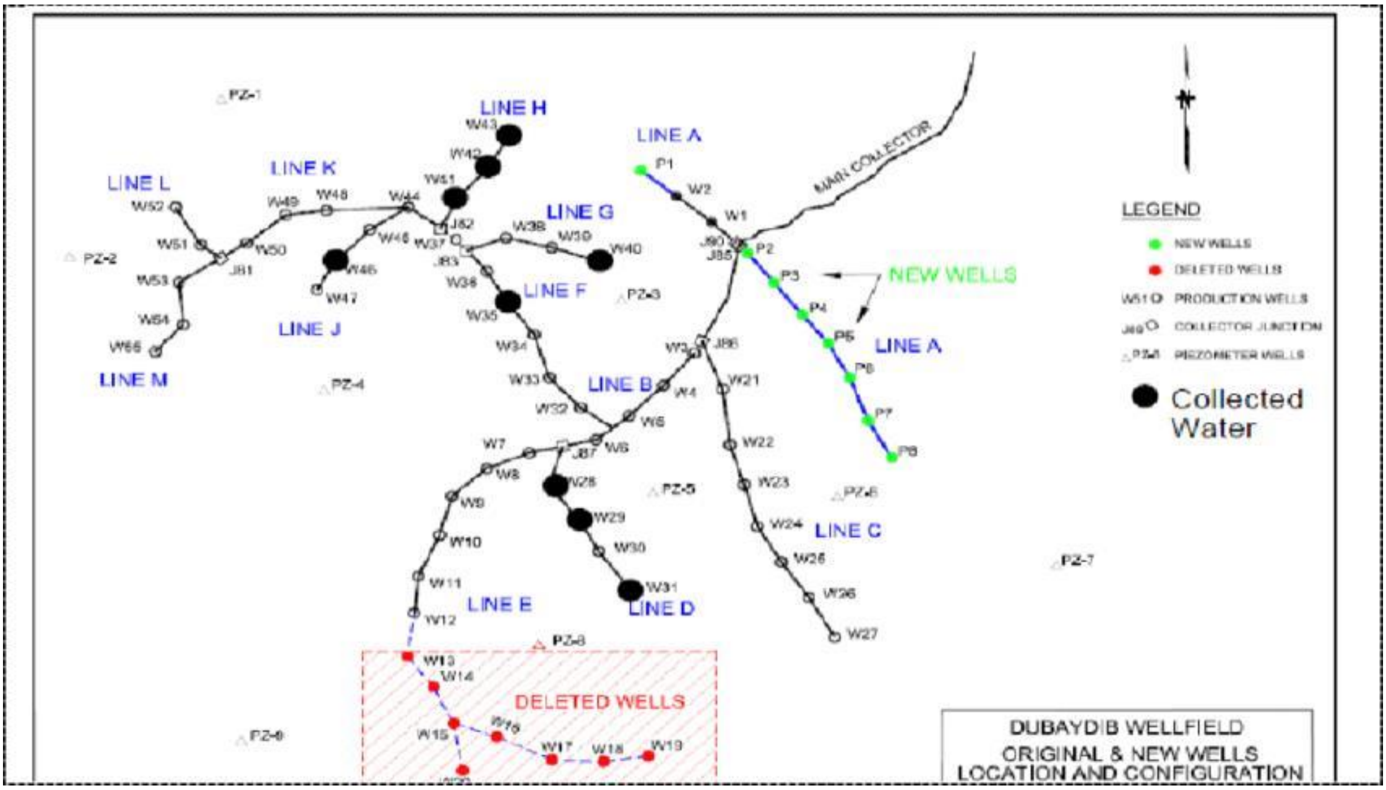


Fig.8.a shows the classification of the Disi wells into categories -depend on location

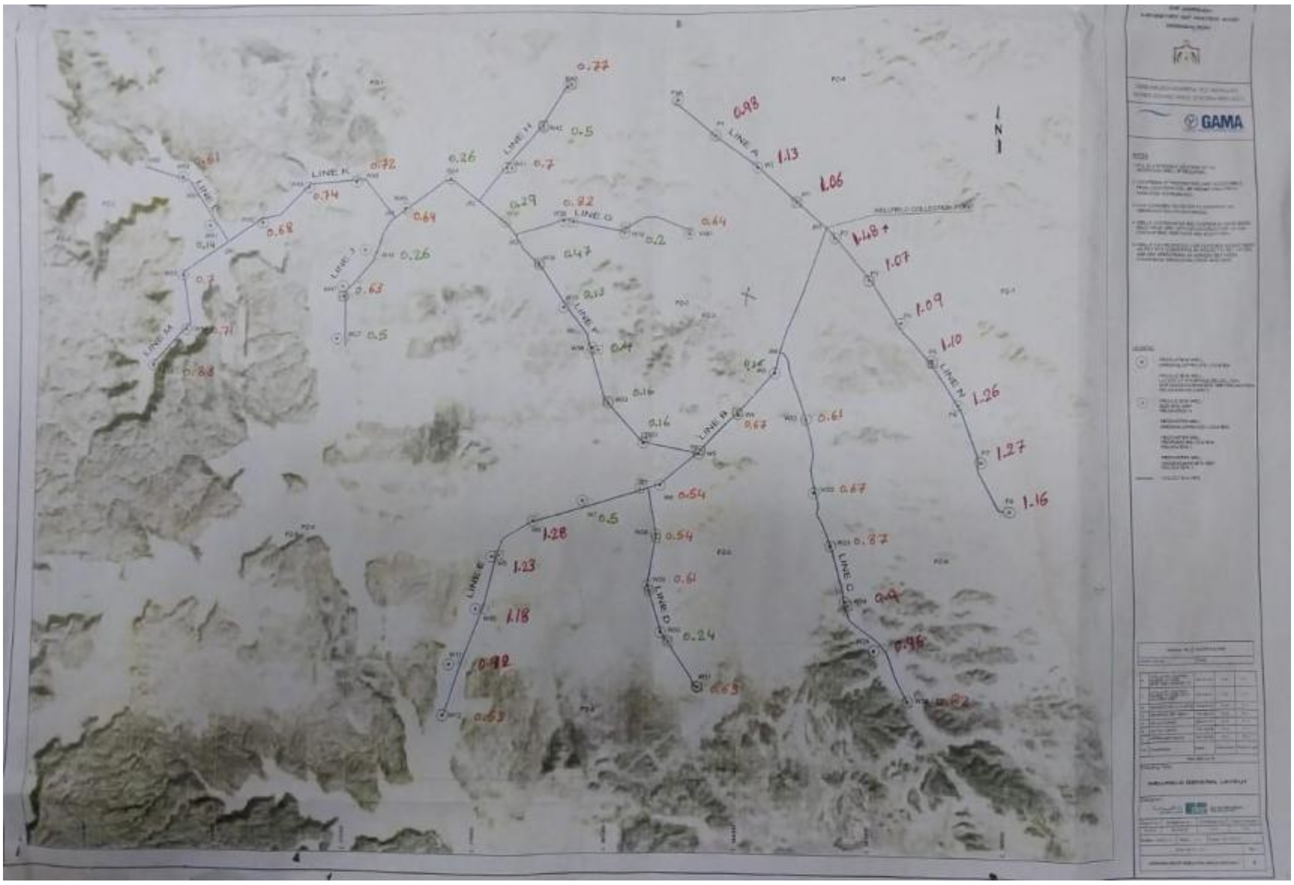


Fig.8.b classification of wells into categories -depend on location

LINE A	LINE D	LINE E	LINE G	LINE F	LINE C	LINE B	LINE H	LINE J	LINE K	LINE L	LINE M
P1	W28	W7	W38	W32	W21	W3	W41	W44	W48	W51	W53
P2	W29	W8	W39	W33	W22	W4	W42	W45	W49	W52	W54
P3	W30	W9	W40	W34	W23	W5	W43	W46	W50		W55
P4	W31	W10		W35	W24	W6		W47			
P5		W11		W36	W25						
P6		W12		W37	W26						
P7					W27						
P8											
W1											
W2											

Table (2) wells names listed in the categories (Line A,B,C,D,E,F,G,H,J,K,L,and M)

LINE A	LINE D	LINE E	LINE G	LINE F	LINE C	LINE B	LINE H	LINE J	LINE K	LINE L	LINE M
P1	W28	W7	W38	W32	W21	W3	W41	W44	W48	W51	W53
P2	W29	W8	W39	W33	W22	W4	W42	W45	W49	W52	W54
P3	W30	W9	W40	W34	W23	W5	W43	W46	W50		W55
P4	W31	W10		W35	W24	W6		W47			
P5		W11		W36	W25						
P6		W12		W37	W26						
P7					W27						
P8											
W1											
W2											

Table (3) well names analyzed through 2023(listed in black), and wells collected and analyzed in 2024(listed in red).

	Alpha (Bq/L)	Beta(Bq/l)	Ra226 (Bq/L)	Ra 228 (Bq/L)	DOSE(msv/y)
LINE A	3.53	3.58	0.67	1.98	1.14
LINE D	1.92	2.40	0.22	0.92	0.51
LINE E	4.26	3.66	0.44	1.67	0.93
LINE G	3.75	3.21	0.33	0.95	0.55
LINE F	1.85	1.98	0.22	0.55	0.32
LINE C	2.75	2.42	0.45	1.31	0.75
LINE B	3.06	2.51	0.25	0.94	0.52
LINE H	3.51	3.04	0.29	1.18	0.65
LINE J	2.52	1.85	0.23	0.56	0.33
LINE K	3.82	3.10	0.36	1.20	0.68
LINE L	1.86	1.43	0.29	0.76	0.44
LINE M	3.07	2.66	0.49	1.40	0.81

Table #4 indicates the higher dose achieved through the Disi wells (Line A) and the lowest dose (Line F and line J)
See Fig.9 below.

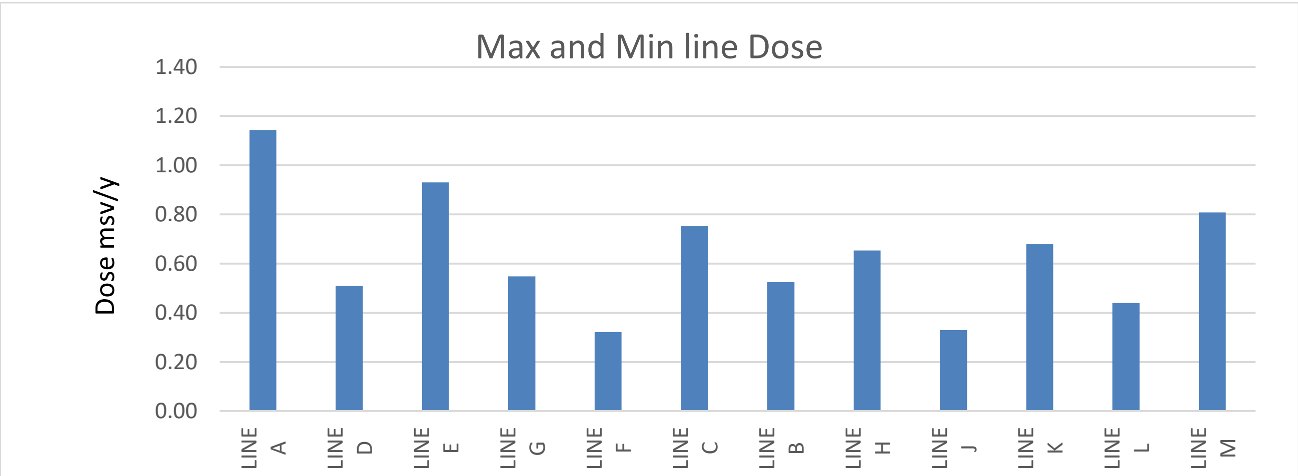


Fig.9 shows that the max dose is at location Line A (P1-P8, W1&W2) while the min dose at Line F (W32,W33,W34,W35,W36 and W37),and line J (W44,W45,W56&W47)

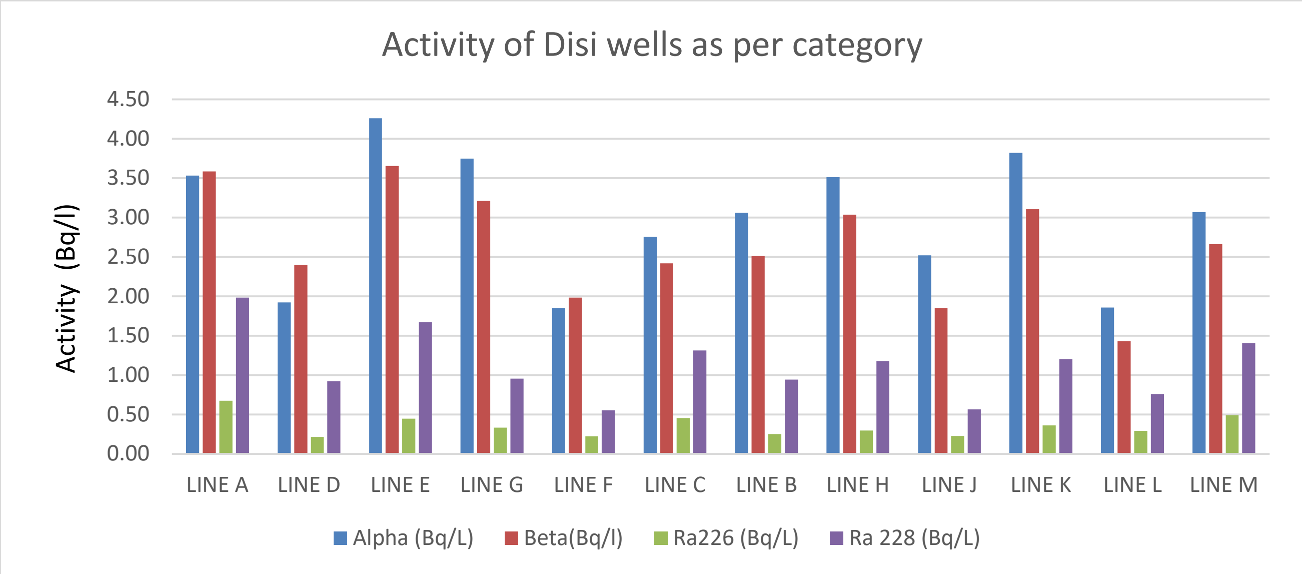


Fig.10 shows the Avg of the activity for Radium in the Disi wells as per categories shown in the Fig#8

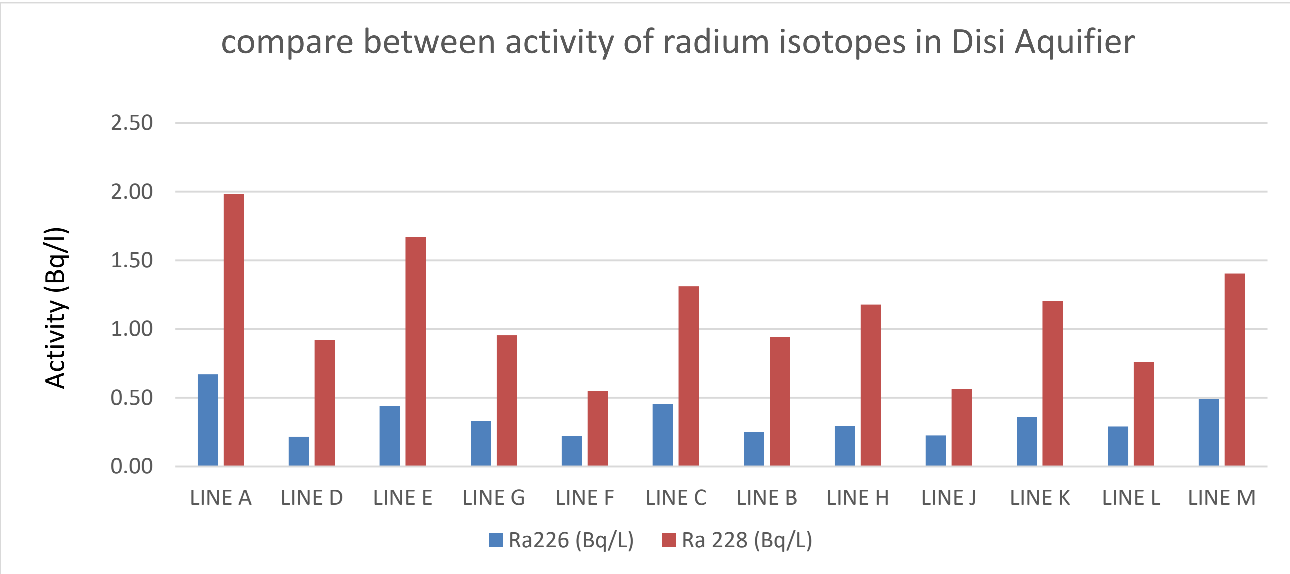


Fig.11 shows the characteristics of Rum Aquifer -in which Disi wells locates- , Ra^{228} activity consider to be higher than the Ra^{226} activity (about 3 times higher).

WELL NAME	Dose(mSv/y) 2024	Dose (msv/y) 2022
ISO-P1	0.98	0.99
ISO-P2	1.42	1.67
ISO-P3	1.08	1.06
ISO-P4	1.06	1.07
ISO-P5	1.05	1.00
ISO-P6	1.29	1.12
ISO-P7	1.25	1.12
ISO-P8	1.19	1.43
ISO-W1	0.99	1.10
ISO-W2	1.08	1.01
ISO-W3	0.36	0.44
ISO-W4	0.59	0.62
ISO-W5	0.45	0.52
ISO-W6	0.52	0.56
ISO-W7	0.33	0.60
ISO-W8	1.40	1.18
ISO-W9	1.34	1.22
ISO-W10	1.14	1.22
ISO-W11	0.79	0.51
ISO-W12	0.46	0.46
ISO-W21	0.53	0.89
ISO-W22	0.57	0.56
ISO-W23	0.88	1.83
ISO-W24	0.88	0.80
ISO-W25	0.88	0.81
ISO-W26	0.79	0.74
ISO-W27	0.46	0.49
ISO-W28	0.47	0.46
ISO-W29	0.57	0.54
ISO-W30	0.36	0.35
ISO-W31	0.63	0.66
ISO-W32	0.16	0.23
ISO-W33	0.12	0.18
ISO-W34	0.34	0.37
ISO-W35	0.13	0.17
ISO-W36	0.47	0.44
ISO-W37	0.33	0.35
ISO-W38	0.77	0.80
ISO-W39	0.21	0.21
ISO-W40	0.63	0.62
ISO-W41	0.63	0.68
ISO-W42	0.53	0.52
ISO-W43	0.80	0.86
ISO-W44	0.19	0.22
ISO-W45	0.24	0.59
ISO-W46	0.25	0.28
ISO-W47	0.59	0.64
ISO-W48	0.72	0.63
ISO-W49	0.70	0.71
ISO-W50	0.62	0.64
ISO-W51	0.18	0.18
ISO-W52	0.71	0.54
ISO-W53	0.64	0.65
ISO-W54	0.80	0.75
ISO-W55	0.99	0.84
MAX	1.42	1.83
MIN	0.12	0.17

Table #5 a AED comparison for the same measured wells through cycle (2021-2022)& cycle (2023-2024).

The above table shows that the characteristics –depend on dose values-of the wells were almost the same for the most them.
And the highest dose was arise in well P2 (Line A), while the min dose is for well W33 (Line F) as shown below

WELL NAME	Dose(msv/y) 2024	Dose(msv/y) 2023
ISO-P2	1.42	1.42
ISO-W33	0.12	0.12

Table #6 Max and Min AED for the measured wells for cycle 2023-2024

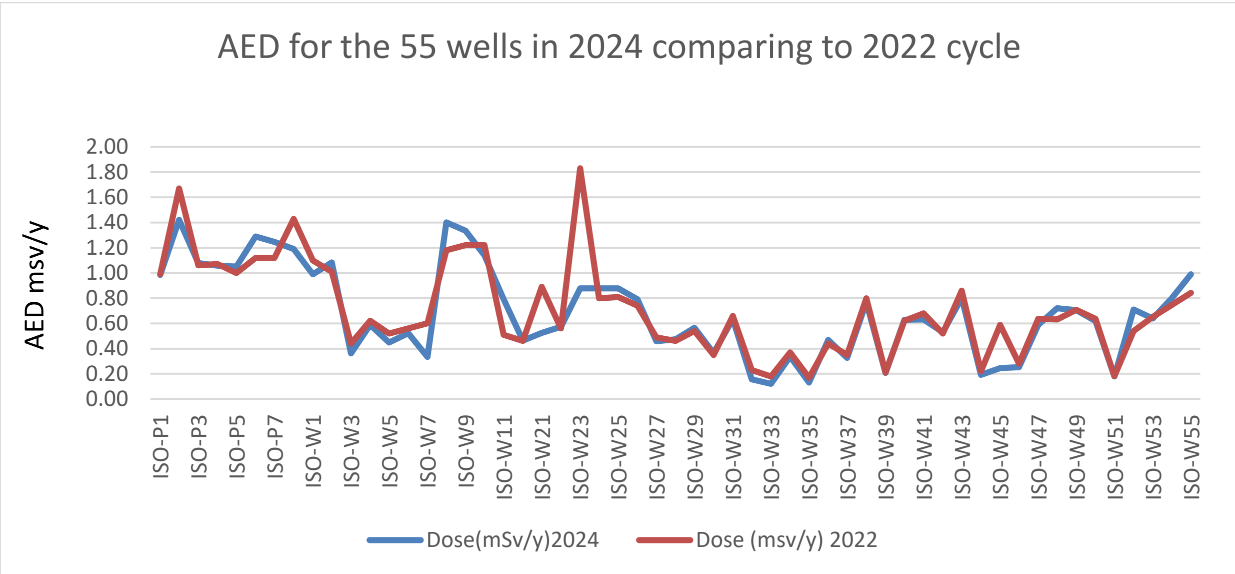


Fig #12 clearly shows that there is consistency between AED through2022 and 2024

The radioactive results for the measured wells as shown in the tables and the charts shows a consistency of data, that there is a wells with high activity and wells with low activity in which there is a slight deviation through years except for the results for W23 (the sample collected in June 2021) after comparing all the well results through years up to 2024 an obvious high activity for both Ra226 and Ra228 appear in the mentioned well , in which raise the dose value as well , but the results for W23 in cycle 2023-2024 matches the historical data ,this well will be under consideration in the next cycle in order to check the reason of this high values , one of the scenarios lead us to the sampling issue .

5.2 PART TWO: Radioactivity in the Delivery points (Blending Points)

MWI must carry out progressive sampling of the operational boreholes (BH) to identify and mitigate the problem, and provide a monthly report (Red Flag report) to the Lenders and the Project Company with the proposed measures to ensure that the blended water output (SA, SB or SC) does not exceed the threshold of 0.5 mSv/y and progress relating to their implementation. Sampling of BH must include the following:

- Total alpha and total beta activity
- Activities for radionuclides including radium (Ra226 and Ra228) as per mentioned in ESMP 2 Rev2
- as per ESMP plan section 3 WATER QUALITY COMPLIANCE: MONITORING AND BLENDING there is two major tanks (AA1 and Dabuk Boaster) established and prepared to receive anon radioactive water from AlZara maen and Zai effluent plant respectively -in addition to the quantity of water supplied from Al-Disi line

The required monitoring regime under this ESMP Part 2, for the Disi Project is generally based on the principles of the Jordanian Drinking Water Standards 286:2015 – 6th Edition, the WHO Guidelines for Drinking-Water Quality, and information provided by MWI to Lenders prior to commencement of the project.

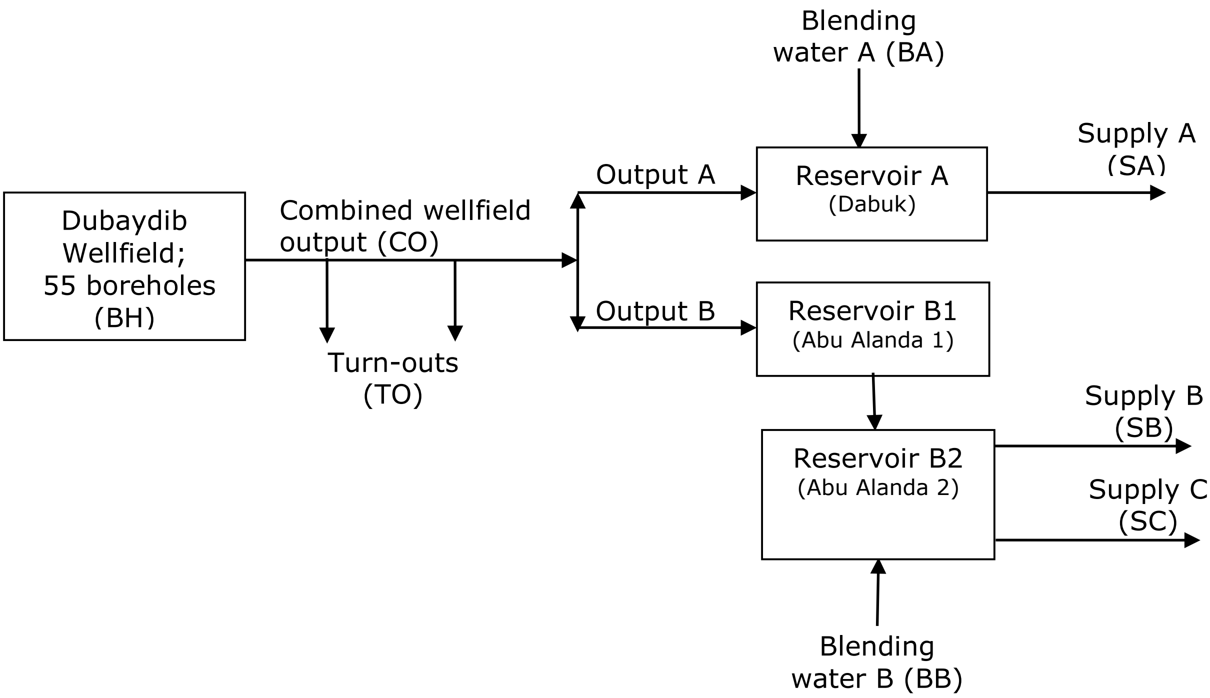


Fig #13 Schematic diagram of the Delivery points (Blending Points)

The programmed automatic sampler continuously takes an equal sized sample each day and collects it in a pre-acidified 20 liter container which is collected at the end of each month for analysis and replaced with another one to repeat the procedure.
A reliable monitoring procedure ensures that a representative sample is available for one full month. The monitored blending and delivery points are:-

1- **Dabuq reservoir** The main inflow from Disi
2- **Boaster Dabuq** (point SA in Fig.12) which represents Dabuk network (Dabuk after blending).
3- **Shmisani** another network point which has additional source for blending water after Boster Dabuk.

4- **Al Margab** (point SB in Fig.12) which represents Abu Alanda network (Abu Aland after blending).
The Report depend on results from the above sampling requirements with respect to the level of radioactivity in the water from the operating boreholes (BH), combined flow from the wellfield (CO), blending water blended water and water at turn
Abu Alanda and boaster blended with Zara Maen and Zai respectively, because after radiological analysis for both water sources, the AED <0.02 msv/y which is the appropriate water quality to mix with both (Abu Alanda and Boaster).
As shown in Table #7 (A&B) the data is for 2023 &2024 respectively

Month	Date of colllection	Total Quantity Supplied from Disi (m3/month)	Equivalent Dose in Disi line mS/year	Quantity Supplied from Zara-Main to Abu Alanda Res. (m3/month)	Quantity Supplied from Disi to Abu Alanda Res. (m3/month)	Mixing ratio (ZARA-Main) /Disi in Abu Alanda Res. %	Equivilent Dose in Abu Alanda Res. mS/year	Quantity Supplied from Zai to Dabouk Booster Res. (m3/month)	Quantity Supplied from Disi to Dabouk Booster Res. (m3/month)	Mixing ratio Zai /Disi in Dabouk Booster Res. %	Eqivalent Dose in Dabouk Booster Res. mS/year	Eqivalent Dose in Shmisani Res. mS/year	Quantity Supplied from AA1 to Zatary Res. (m3/month)	Eqivalent Dose in Zatary Res. mS/year
Jan	31/1/2023	9495664	0.68	712490	3734672	0.19	0.55	3479108	5760992	0.60	0.48	0.26		
Feb	1/3/2023	8548544	0.61	676770	3503264	0.19	0.56	3350465	5045280	0.66	0.47	0.29		
Mar	30/3/2023	9514018	0.67	705970	3891966	0.18	0.55	3843687	5622052	0.68	0.48	0.24		
Apr	1/5/2023	9187730	0.65	701800	4000978	0.18	0.53	4058902	5186752	0.78	0.43	0.19		
May	30/5/2023	9469296	0.61	727250	4148432	0.18	0.52	4655708	5320864	0.87	0.50	0.21		
Jun	30/6/2023	9185344	0.64	676600	4078976	0.17	0.56	4863188	5106368	0.95	0.41	0.25		
Jul	31/7/2023	9117629	0.66	668300	3475624	0.19	0.57	4956685	5272860	0.94	0.44	0.23	369145	0.09
Aug	31/8/2023	9119083	0.69	781040	3500734	0.22	0.61	4945962	5265220	0.94	0.46	0.32	353129	0.11
Sep	1/10/2023	9165574	0.69	754004	3883949	0.19	0.56	4693750	5101120	0.92	0.45	0.27	180505	0.10
Oct	30/10/2023	9641902	0.71	989965	3812601	0.26	0.49	4248588	5605116	0.76	0.44	0.27	224185	0.10
Nov	30/11/2023	9061748	0.69	1047774	3590167	0.29	0.47	3645910	5402406	0.67	0.46	0.30	69175	<0.09
Dec	31/12/2023	8939360	0.62	897168	3663520	0.24	0.56	4108085	5275840	0.78	0.44	0.30		
Average			0.66	778260.92	3773740.3	0.21	0.543707			0.80	0.45423667	0.26251		0.10
Total (m3/year)		110445892		9339131	45284883			50850038	63964870				1196139	

Table #7A: mixing ratios and dose values for the year 2023

Month	**Date of collection**	**Total Quantity Supplied from Disi** **(m^3/month)**	**AED in Disi line** **mSv/year**	**Quantity Supplied from Zara-Main to Abu Alanda Res.** **(m^3/month)**	**Quantity Supplied from Disi to Abu Alanda Res.** **(m^3/month)**	**Mixing ratio (ZARA-Main) /Disi in Abu Alanda** **%**	**AED in Abu Alanda Res.** **mSv/year**	**Quantity Supplied from Zai to Dabouk Booster Res.** **(m^3/month)**	**Quantity Supplied from Disi to Dabouk Booster Res.** **(m^3/month)**	**Mixing ratio Zai /Disi in Dabouk Booster Res.** **%**	**AED in Dabouk Booster Res.** **mSv/year**	**AED in Shmisani Res.** **mSv/year**
Jan	31/1/2024	9814848	0.63	490758	4088704	0.12	0.59	3713295	5726144	0.65	0.44	0.22
Feb	30/2/2024	9180224	0.69	480042	3853184	0.12	0.60	4127753	5327040	0.77	0.42	0.27
Mar	31/3/2024	9729344	0.65	482110	4027104	0.12	0.59	4072121	5702240	0.71	0.45	0.29
Apr	1/5/2024	9491344	0.72	693140	3893840	0.18	0.54	3808183	5597504	0.68	0.45	0.25
May	30/5/2024	9824544	0.67	600244	4071168	0.15	0.59	4189433	5753376	0.73	0.44	0.20
Jun	1/7/2024	9512192	0.66	534700	4013120	0.13	0.61	4736827	5499072	0.86	0.47	0.34
Jul	1/8/2024	9722928	0.66	688468	4089520	0.17	0.61	4762122	5633408	0.85	0.44	0.26
Aug	1/9/2024	9820816	0.67	764344	4126672	0.19	0.63	4751120	5694144	0.83	0.44	0.25
Sep	1/10/2024	9508864	0.65	934994	3988224	0.23	0.56	4552983	5520640	0.82	0.44	0.32
Oct	31/10/2024	9508200	0.62	1185814	3934920	0.30	0.56	3762636	5573280	0.68	0.44	0.29
Nov	1/12/2024	9496816	0.71	1066380	3844048	0.28	0.52	3680573	5652768	0.65	0.49	0.31
Dec	2/1/2025	9814848	0.71	490758	4088704	0.12	0.55	3713295	5726144	0.65	0.49	0.33
Average			0.67			0.18	0.58			0.75	0.45	0.28
Total (m3/year)		115424968		8411752	48019208			49870341	67405760			

Table #7B: mixing ratios and dose values for the year 2024

Month	Ra226 in Disi line	Ra228 in Disi line	AED in Disi line	Ra226 in Abu Alanda Res.	Ra228in Abu Alanda Res.	AED in Abu Alanda Res	Ra226 in Dabouk Booster Res.	Ra228 in Dabouk Booster Res.	AED inDabouk Booster Res	Ra226 in Shamisani Res.	Ra228 in Shamisani Res.	AED in Shamisani Res	Ra226 in Zatary Res.	Ra228 in Zatary Res.	AED in Zatary Res.
Month	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year
Jan	0.37	1.20	0.68	0.26	0.99	0.55	0.23	0.85	0.48	0.17	0.45	0.26			0.00
Feb	0.31	1.08	0.61	0.28	1.00	0.56	0.25	0.84	0.47	0.14	0.52	0.29			0.00
Mar	0.40	1.17	0.67	0.29	0.97	0.55	0.25	0.85	0.48	0.23	0.39	0.24			0.00
Apr	0.28	1.18	0.65	0.25	0.96	0.53	0.17	0.79	0.43	0.14	0.33	0.19			0.00
May	0.31	1.08	0.61	0.25	0.93	0.52	0.24	0.9	0.50	0.12	0.37	0.21			0.00
Jun	0.31	1.14	0.64	0.25	1.00	0.56	0.22	0.73	0.41	0.15	0.43	0.25			0.00
Jul	0.34	1.17	0.66	0.31	1.00	0.57	0.21	0.78	0.44	0.18	0.39	0.23	<0.12	<0.13	<0.50
Aug	0.36	1.23	0.69	0.31	1.08	0.61	0.24	0.81	0.46	0.17	0.56	0.32	<0.12	0.16	<0.50
Sep	0.35	1.23	0.69	0.29	0.99	0.56	0.27	0.78	0.45	0.17	0.47	0.27	<0.12	0.14	<0.50
Oct	0.34	1.27	0.71	0.25	0.87	0.49	0.23	0.77	0.44	0.21	0.46	0.27	<0.12	0.14	<0.50
Nov	0.34	1.23	0.69	0.26	0.83	0.47	0.24	0.81	0.46	0.21	0.52	0.30	<0.12	<0.13	<0.50
Dec	0.31	1.10	0.62	0.26	1.01	0.56	0.22	0.79	0.44	0.19	0.52	0.30			0.00
Avg	0.34	1.17	0.66	0.27	0.97	0.54	0.23	0.81	0.45	0.17	0.45	0.26	<0.12	0.15	<0.50

Table 8.a shows monthly radioactive indicators of the four delivery/blending points through 2023

	Ra226 in Disi line	**Ra228 in Disi line**	AED in Disi line	**Ra226 in Abu Alanda Res.**	**Ra228in Abu Alanda Res.**	Equivalent Dose in Abu Alanda Res	**Ra226 in Dabouk Booster Res.**	**Ra228 in Dabouk Booster Res.**	Equivalent Dose inDabouk Booster Res	**Ra226 in Shamisani Res.**	**Ra228 in Shamisani Res.**	Equivalent Dose in Shamisani Res
Month	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year
Jan	0.32	1.13	**0.63**	0.30	1.04	**0.59**	0.21	0.78	**0.44**	0.16	0.38	**0.22**
Feb	0.35	1.23	**0.69**	0.26	1.08	**0.60**	0.19	0.76	**0.42**	0.20	0.46	**0.27**
Mar	**0.34**	**1.15**	**0.65**	**0.27**	**1.07**	**0.59**	**0.22**	**0.81**	**0.45**	**0.18**	**0.50**	**0.29**
Apr	0.32	1.30	**0.72**	0.23	0.98	**0.54**	0.20	0.81	**0.45**	0.16	0.43	**0.25**
May	0.38	1.18	**0.67**	0.31	1.05	**0.59**	0.23	0.77	**0.44**	0.16	0.34	**0.20**
Jun	0.34	1.18	**0.66**	0.26	1.11	**0.61**	0.22	0.84	**0.47**	0.18	0.60	**0.34**
Jul	0.45	1.12	**0.66**	0.34	1.07	**0.61**	0.25	0.78	**0.44**	0.17	0.45	**0.26**
Aug	0.32	1.20	**0.67**	0.29	1.13	**0.63**	0.24	0.77	**0.44**	0.15	0.43	**0.25**
Sep	0.30	1.16	**0.65**	0.26	1.00	**0.56**	0.21	0.78	**0.44**	0.16	0.57	**0.32**
Oct	0.34	1.09	**0.62**	0.25	1.01	**0.56**	0.23	0.77	**0.44**	0.16	0.51	**0.29**
Nov	0.35	1.26	**0.71**	0.24	0.94	**0.52**	0.23	0.87	**0.49**	0.2	0.53	**0.31**
Dec	0.44	1.23	**0.71**	0.27	0.98	**0.55**	0.35	0.83	**0.49**	0.26	0.54	**0.33**
Avg			0.67			**0.58**			**0.45**			0.28

Table 8.b shows monthly radioactive indicators of the four delivery/blending points through 2024

Year	**Total Quantity Supplied from Disi**	**AED in Disi line**	**Quantity Supplied from Zara-Main to Abu Alanda Res.**	**Quantity Supplied from Disi to Abu Alanda Res.**	**Mixing ratio (ZARA-Main) /Disi in Abu Alanda Res.**	**AED in Abu Alanda Res.**	**Quantity Supplied from Zai to Dabouk Booster Res.**	**Quantity Supplied from Disi to Dabouk Booster Res.**	**Mixing ratio Zai /Disi in Dabouk Booster Res.**	**AED in Dabouk Booster Res.**	**AED in Shmisani Res.**
	(m^3/Year)	mS/year	(m^3/Year)	(m^3/Year)	%	mS/year	(m^3/Year)	(m^3/Year)	%	mS/year	mS/year
2023	110445892	0.66	9339131	45284883	0.21	0.54	50850038	63964870	0.80	0.45	0.26
2024	115424968	0.67	8411752	48019208	0.18	0.58	49870341	67405760	0.75	0.45	0.28

Table#9 comparing between the two Years of 2023&2024 of supplying amounts and mixing ratios.

	Equivilent Dose Dabuk (main Disi line)mS/year	Equivilent Dose Abu Alanda Res.(Almargab)mS/year	Eqivalent Dose in Dabouk Booster Res.mS/year	Eqivalent Dose Shmisani. mS/year
2024	0.67	0.58	0.45	0.28
2023	0.66	0.54	0.45	0.26

Table 10.shows Avg AED for blending points through 2023 and 2024.

The above tables describes clearly the annual effective dose for the four mixing points (Dabuk,Abu Alanda,Boaster and Alshmesani), comparing the Average data resulted through 2023 with the ones resulted through 2024

As seen in the above tables:
-There is an increment of average results of the annual effective dose for Dabuk Abu Alanda Reservoirs, it’s clearly shown that the AED for Dabuk reservoir mainline increased with a slight percentage , but the AED At Abu Alanada is higher in 2024 rather than in 2023,

- even the mixing ratio slightly decreased, The AED at Dabuk Booster was the same through 2023-2024 and kept within acceptable limits (<0.50msv/y) while the AED in Al Shmesani Res in 2024 is higher than the AED in 2023 but still within acceptable limits, there is two additional supplying water resources at al shmesani (Nwejees and Ras Alien).

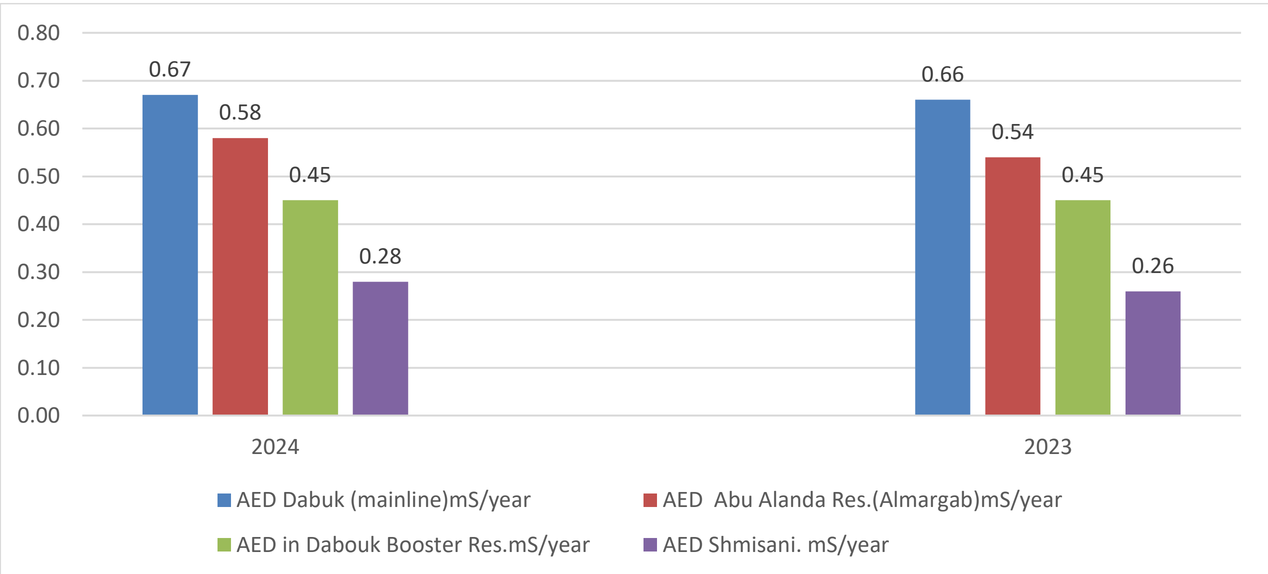


Fig # 14 shows the AED differences for the monitoring points through 2023 comparing to AED resulted in 2024

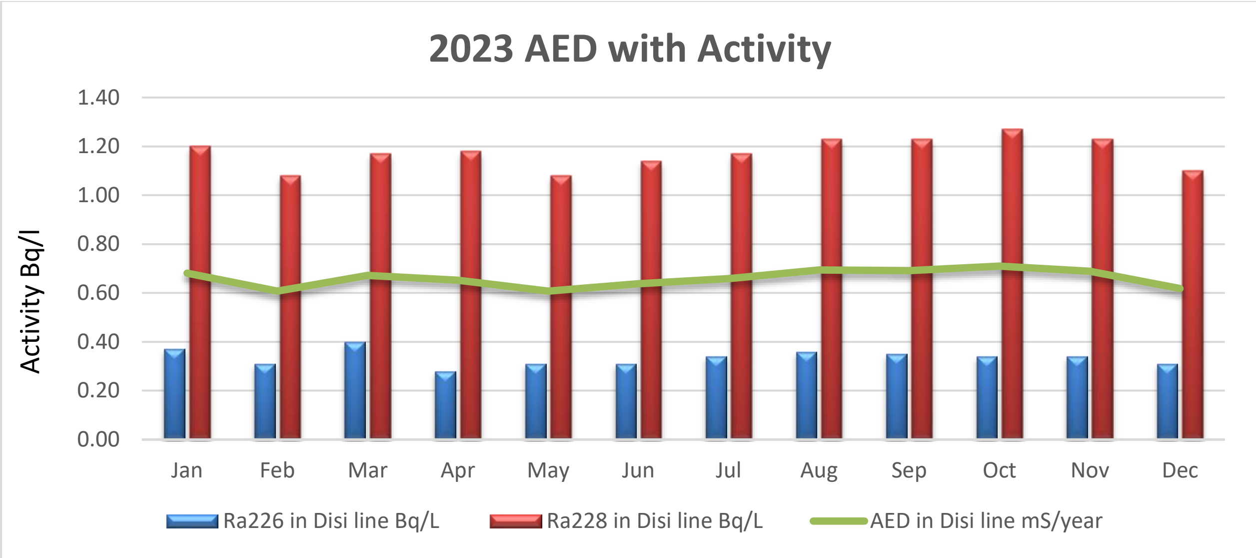
As shown from the previous Tables for the four mixing points:

1- From the table it's clearly shown that the total quantity supplied from disi in 2024 is (115424968m3) which is more than 2023(110445892m3) by 4.5%.
2- The quantity supplied from Zara to Abu Alanda was reduced in 2024 from (9339131to 8411752) by 10%.
3- The total quantity supplied from Disi to Abu Alanda increased from 45284883 to 48019208 by 6%, and the quantity supplied from Zara and Disi to Abu Alanda clearly represented in the mixing ratio, which reduced in 2024 to be 18% while it was 21% in 2023.
   This makes the AED in Abu Alanda higher in 2024
4- In Dabouk Booster the quantity supplied from Zai was reduced in 2024 from 50850038 to 49870341 by 2%, And from the Disi side raised (from 63964870 in 2023 to 67405760 in 2024) by a percentage of 5%.These supplied quantity shown in the mixing ratio percent (0.75 in 2024 while it was 0.80%in 2023).The AED in Dabouk Boaster remains the same (0.45msv/y) which is expected since the mixing ratio reduced in a slight percentage (0.05%).

Comparison of the radioactive indicators for the four monitored points over years

	AED in Dabuk main Disi line	AED in Abu Alanda Res. (Al Margab)	AED in Dabuk Boster Res.
Year	mSv/y	mSv/y	mSv/y
2014	0.70	0.43	0.48
2015	0.70	0.43	0.37
2016	0.73	0.52	0.34
2017	0.68	0.54	0.33
2018	0.70	0.55	0.36
2019	0.68	0.46	0.36
2020	0.71	0.51	0.39
2021	0.64	0.58	0.40
2022	0.63	0.57	0.43
2023	0.66	0.54	0.45
2024	0.67	0.58	0.45

Table #11 comparison in AED for each point over years which evident that values over years are in consistence, (note that the Max AED permitted in Jordan is 0.50 msv/y)



Fig# 15 a

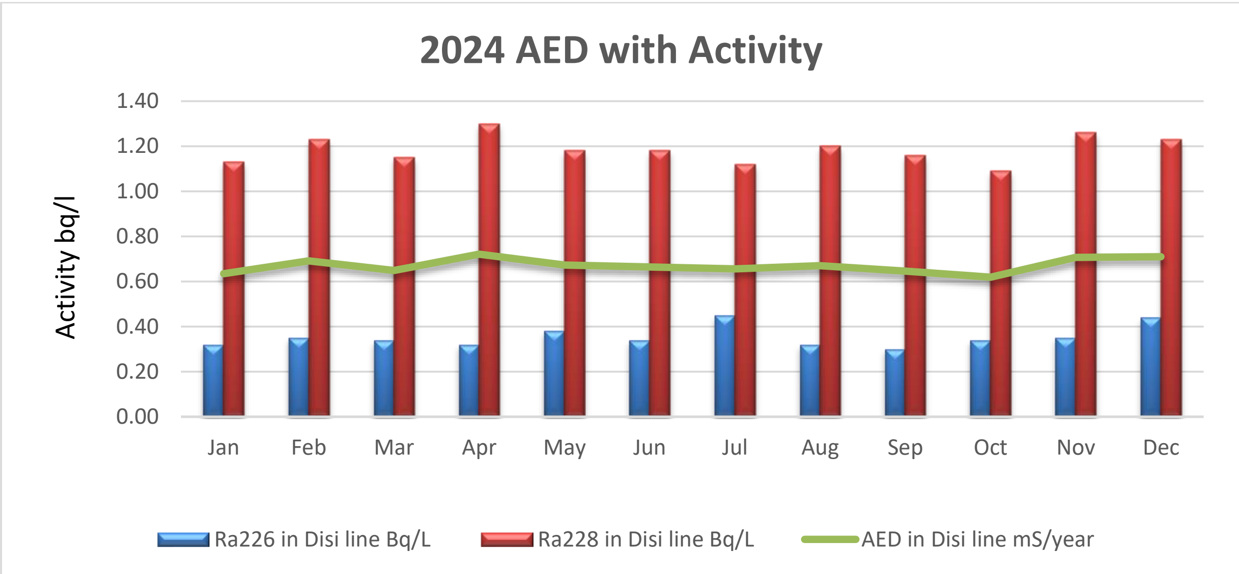


Fig # 15 b

Fig# 15a+b: shows the $Ra^{226}$and Ra^{228} activities comparing to the resulted AED through months 2023 and 2024up to Dec and clearly seen the effect of Ra228 on dose .and as seen ,the behavior of Disi wells (Rum Aquifer) its seen that Ra228is usually three times of Ra226 activity, in addition the AED equation specify the factor of Ra228 to be 0.504 with 0.204 of Ra226,

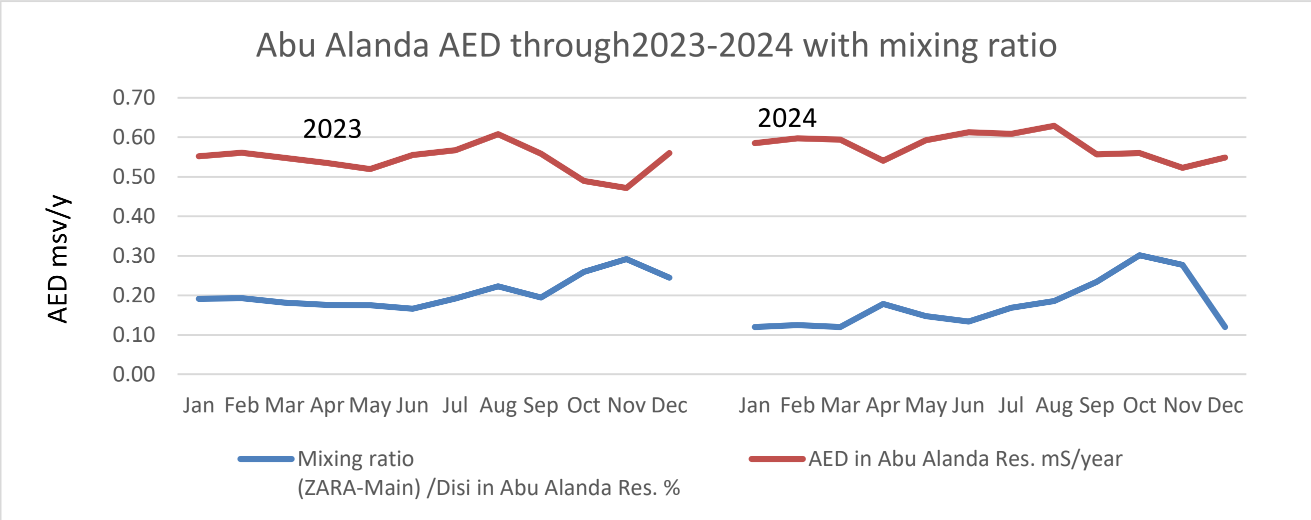


Fig # 16: shows the consistency of AED at Abu Alanda with the mixing ratios applied, increasing the mixing ratios will decrease the AED and with decreasing the mixing ratios will increase the AED.

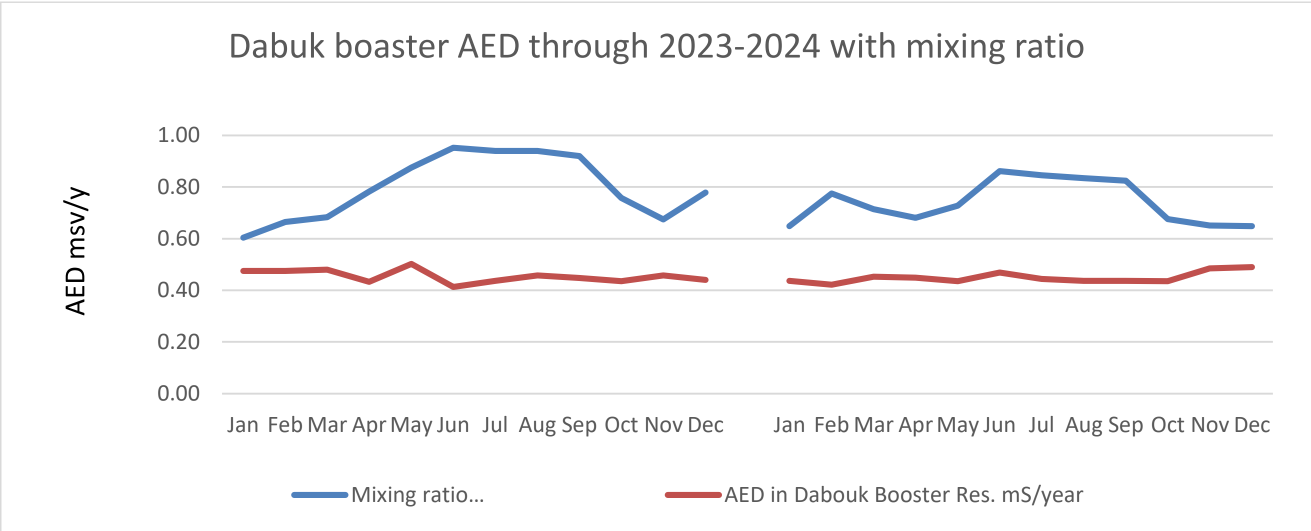


Fig # 17 shows the consistency of AED increment on mixing ratios, with the effect on AED (decreasing) as Well.

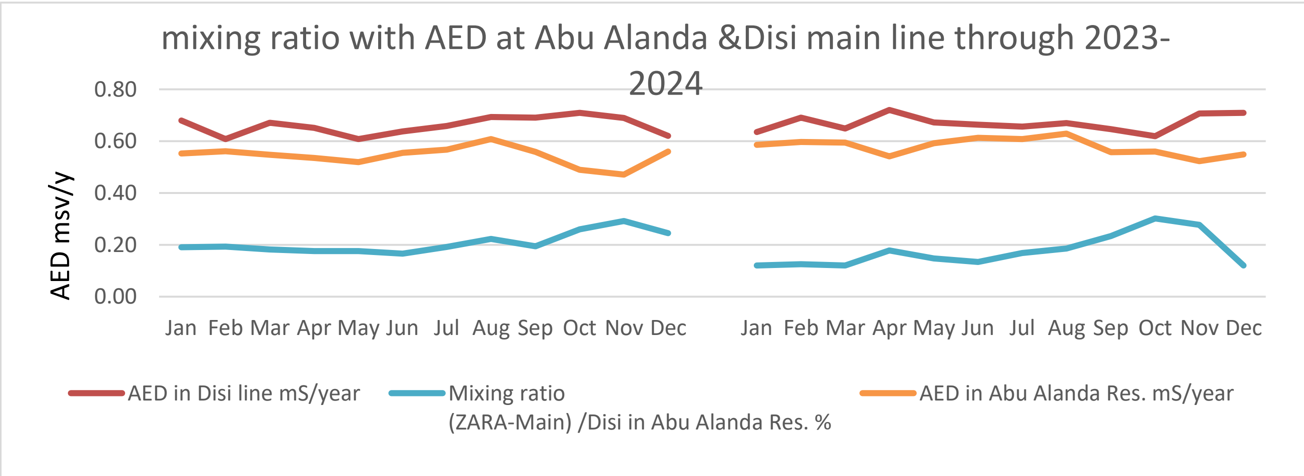


Fig # 18 shows the effect of mixing ratios on AED at Disi line and Abu Alanda

5.2Part three; Radioactivity in the Combined Wellfield

Combined wellfield Results:

Combined wellfield is a two components tank where the water from the 55 well field are collected in at Al Mudawara in order to be pumped to Amman city.

Radioactivity Results in the combined well field tank (CO) reflects radioactivity concentration of the operating wells mixture at the time of sampling.

Round no.	ID	collection date	Alpha (Bq/L)	Beta(Bq/l)	Ra226 (Bq/L)	Ra 228 (Bq/L)	Dose(mSv/y)	O18	D	T	C13	Rn222	Pb210
Jan-23	107	18/1/2023	4.05	2.28	0.43	1.23	0.71	-6.29	-36.97	<1.2	-5.3	26.45	<0.02
Mar-23	213	16/3/2023	3.38	2.51	0.34	1.18	0.66	-6.35	-38.47	<1.2	-4.96	12.23	<0.02
Jul-23	408	13/7/2023	2.23	2.64	0.33	1.17	0.66	-5.97	-36.76	1.29	-5.49	canceled	<0.02
Oct-23	634	19/10/2023	1.46	2.09	0.32	1.26	0.70	-6.6	-37.82	<1.2	-6.35	Failed	<0.02
Nov-23	754	22/11/2023	3.81	2.72	0.33	1.07	0.61	-6.64	-37.67	<1.2	-6.84	26.26	0.02
Mar-24	197	26/3/2024	2.96	2.97	0.36	1.14	0.65	-6.13	-39.25	<1.2	-3.69	15.5	0.02
Jul-24	422	18/7/2024	2.63	2.54	0.35	1.27	0.71	-6.86	-36.72	<1.2	out of work	14.8	0.02
Oct-24	578	3/10/2024	3.00	2.68	0.32	0.91	0.52	-6.62	-39.53	<1.2	out of work	12.99	0.03
Dec-24	685	12/12/2024	2.25	2.81	0.39	1.33	0.75	-6.37	-37.5	<1.2	out of work	15.87	0.03

Table #12 summarize the radiological and stable (O18&D) results of the combined well through 2023-2024.

Consider the following for the above table:

-Sample that collected for Ra222 in July 2023 has been cancelled since the sample received with cocktail contamination around the bottle ,which might affect the instrument, on the other hand the spoiling of the cocktail might include part of the sample with it , and this is will affect the actual value of Ra222 in the sample .

-Sample that collected for Ra222 in October 2023 failed in counting (samples were collected in the field and must be received to be counted not more than three hours to ensure that the following daughters will vanish short lived progenies (218Po, 214Pb, 214Bi, 214Po) but in this sample it was received in more than 3 hours which build up new short lived progenies.

-At the beginning of July 2024 **Cavity ring-down spectroscopy** that used to measure carbon 13 has been considered to be out of service.

Round no.	ID	collection date	Alpha (Bq/L)	Beta(Bq/l)	Ra226 (Bq/L)	Ra 228 (Bq/L)	Dose(mSv/y)
Jan-23	107	18/1/2023	4.05	2.28	0.43	1.23	0.71
Mar-23	213	16/3/2023	3.38	2.51	0.34	1.18	0.66
Jul-23	408	13/7/2023	2.23	2.64	0.33	1.17	0.66
Oct-23	634	19/10/2023	1.46	2.09	0.32	1.26	0.70
Nov-23	754	**22/11/2023**	3.81	2.72	0.33	1.07	0.61
Mar-24	197	**26/3/2024**	2.96	2.97	0.36	1.14	0.65
Jul-24	422	**18/7/2024**	2.63	2.54	0.35	1.27	0.71
Oct-24	578	3/10/2024	3.00	2.68	0.32	0.91	0.52
Dec-24	685	12/12/2024	2.25	2.81	0.39	1.33	0.75
		AVG	2.86	2.58	0.35	1.17	0.66

Table #13 shows the consistency in AED for the CO well through 2023and 2024.

The combined well field reservoir is sampled quarterly to obtain total alpha, total beta, Ra^{226} concentration, Ra^{228} concentration, Pb^{210} concentration, and radon concentration Rn^{222}. It is noted that the averages of any single indicator are similar over the years.

	2023		
	Ra226 (Bq/L)	Ra 228 (Bq/L)	Dose(mSv/y)
combined wellfield	0.35	1.18	0.67
	2024		
combined wellfield	0.36	1.16	0.66

Table #14 shows the radioactivity of Radium ^{226}and ^{228} and the AED as well through 2023, 2024 for the combined well it's clearly shown that there is no obvious deviation in AED.

6. CONCLUSIONS

6.1 The highest values of AED for the sampled wells are for the wells in line A on the Disi wellfield map then getting down as we go from E up to M,C,K,H,G,B,D,L,J,F)

The above results is an indication for the 55 wells that have been sampled through 2023 &2024(Table #3)
Fig # 9, 10&11 shows clearly the highest and lowest AED due to the measured ones in 2023 and 2024 which shows that the highest AED is for P2 (line A), while the lowest one is for W33 (line F) as shown in Table #6
Knowing the highest and lowest AED for the wells can help in pumping issues (to select the appropriate well for pumping amounts especially due to the season)

6.2 No significant variation in the radioactivity results of the 55wellfield over years.

The radioactive results for the measured wells as shown in the tables and the charts shows a consistency of data , that there is a wells with high activity and wells with low activity in which there is a slight deviation through years .as shown in Table #5 (a comparison for the measured wells through 2023&2024).

The majority of the AED in well and post-transfer is due to the contribution of Ra^{228}, which is a member of the thorium decay chain. $Radium^{226}$ was also noted but did not constitute the main component in terms of AED.

6.3 Dabuk network has fully complied with Jordanian standards over the years while still Abu Aland face a slight raise in AED in some months.

Samples that have been collected in monthly basis (composite samples) for Dabuk which receive a supplying amount of water from Disi main line and blended by a supplying amount from Zara –main shows a the success of keeping the AED to be <0.50msv/y (JS of AED), with an average of 0.45msv/y in both 2023&2024 , as well as Al Shmesani Reservoir that achieve AED of 0.27msv/y as an average for both two years.

On the other hand, the AED for Abu Alanda still exceeds slightly the JS with an average of 0.56 msv/y

6.4 The results of the combined tank are consistent with the results of the 55 wellfields and the results of Dabuk (main line of Disi)

As described in section 5.3 and clarified through Table # 12 and 13 the combined well field through 2023up to the end of 2024 keep it's AED values with an average of 0.66msv/y which slightly lower than the AED for the previous year (0.69msv/y) but within the range over the previous years also.

7 Recommendation

7.1 Commissioning an additional automatic sampling device at Abu Alanda reservoir,

To collect a composite sample to flow into the tank, which facilitates comparison of the radiological results entering, with the results of the mixed water from Al Margab.

7.2 To arrange "if applicable "to increase the pumping from wells in line F&J and reduce the pumping amount from line A

As shown from the results that line A has the max values of AED and by reducing the pumping from such wells , we can reduce the activity resulted from mixing those water amounts with Al-Zara maen stream , which will lead to minimize the AED at Abu Alanda

7.3 Increase amount of blending from Al-Zara maen if the recommendation in point 7.2 is not applicable for blending with Abu Alanda water.

For certain months Al Margab AED was more than the acceptable Jordanian limit, it is Recommended to **increase the proportion of Zara main water free of radioactivity to reduce AED to meet Jordanian standards or to find another sources** which are appropriate in quality for blending

7.4 Provide the Water Authority with the schedule with the time and date of cleaning the three tanks

Abu Alanda,Al Margab and Boster Dabuk for examining the radioactivity of sediments and estimating its effect on radiological results trying to explain the illogical increase of radioactivity results in Al Margab than that of Dabuk reservoir.

8. Appendices

8.1 Appendix-1 shows radioactive results of the 55 wells of Disi through 2023-2024

Table # 15 Results of Alpha, Beta, Ra226, Ra228 and Does Coefficient, of all operating boreholes (BH) (the 55 wells in the Disi well field)

WELL NAME	Alpha (Bq/L)	Beta(Bq/l)	Ra226 (Bq/L)	Ra 228 (Bq/L)	Dose(mSv/y)	decision
ISO-P1	4.65	3.19	0.64	1.69	0.98	exceed the limit
ISO-P2	5.84	4.69	0.78	2.50	1.42	exceed the limit
ISO-P3	4.46	3.65	0.58	1.90	1.08	exceed the limit
ISO-P4	4.03	3.7	0.58	1.86	1.06	exceed the limit
ISO-P5	3.28	3.2	0.54	1.86	1.05	exceed the limit
ISO-P6	1.13	3.52	0.78	2.24	1.29	exceed the limit
ISO-P7	1.91	3.87	0.61	2.22	1.25	exceed the limit
ISO-P8	1.85	3.17	0.66	2.09	1.19	exceed the limit
ISO-W1	4.5	3.08	0.87	1.61	0.99	exceed the limit
ISO-W4	2.99	2.53	0.31	1.04	0.59	exceed the limit
ISO-W1	3.39	3.24	0.71	1.68	0.99	exceed the limit
ISO-W2	3.64	3.76	0.68	1.87	1.08	exceed the limit
ISO-W3	1.35	1.57	0.22	0.63	0.36	accepted
ISO-W4	2.99	2.53	0.31	1.04	0.59	exceed the limit
ISO-W5	3.16	2.68	<0.15	0.83	0.45	accepted
ISO-W6	3.04	2.33	0.18	0.96	0.52	exceed the limit
ISO-W7	2.34	1.94	<0.15	0.60	0.33	accepted
ISO-W8	2.16	3.41	0.55	2.71	1.40	exceed the limit
ISO-W9	6.63	5.06	0.73	2.35	1.34	exceed the limit
ISO-W10	6.18	5.24	0.53	2.04	1.14	exceed the limit
ISO-W11	3.35	2.31	0.27	1.46	0.79	exceed the limit
ISO-W12	4.9	3.97	0.14	0.86	0.46	accepted
ISO-W21	2.53	1.71	0.35	0.90	0.53	exceed the limit
ISO-W22	2.06	2.21	0.26	1.03	0.57	exceed the limit
ISO-W23	3.37	2.8	0.59	1.50	0.88	exceed the limit
ISO-W24	3.01	2.76	0.59	1.50	0.88	exceed the limit
ISO-W25	3.27	2.84	0.52	1.53	0.88	exceed the limit
ISO-W26	3.19	2.62	0.41	1.40	0.79	exceed the limit
ISO-W27	2.1	2.04	0.24	0.81	0.46	accepted
ISO-W28	0.88	1.28	0.22	0.85	0.47	accepted
ISO-W29	0.98	1.5	0.20	1.04	0.57	exceed the limit
ISO-W30	0.74	0.9	0.20	0.64	0.36	accepted
ISO-W31	0.98	1.82	0.24	1.16	0.63	exceed the limit
ISO-W32	0.89	0.75	<0.12	0.26	0.16	accepted

ISO-W33	0.33	0.59	<0.12	0.19	0.12	accepted
ISO-W34	1.57	1.39	<0.12	0.62	0.34	accepted
ISO-W35	0.78	0.51	<0.12	0.21	0.13	accepted
ISO-W36	1.81	2.26	0.22	0.84	0.47	accepted
ISO-W37	1.70	1.36	<0.12	0.60	0.33	accepted
ISO-W38	3.03	3.04	0.35	1.38	0.77	exceed the limit
ISO-W39	0.88	0.69	<0.12	0.36	0.21	accepted
ISO-W40	1.79	2.47	0.31	1.12	0.63	exceed the limit
ISO-W41	3.62	2.92	0.22	1.16	0.63	exceed the limit
ISO-W42	2.29	2.1	0.24	0.95	0.53	exceed the limit
ISO-W43	4.62	4.09	0.42	1.42	0.80	exceed the limit
ISO-W44	1.9	1.18	<0.13	0.33	0.19	accepted
ISO-W45	4.14	2.98	0.21	0.40	0.24	accepted
ISO-W46	1.38	0.97	<0.12	0.45	0.25	accepted
ISO-W47	2.65	2.27	0.24	1.07	0.59	exceed the limit
ISO-W48	4.08	3.22	0.36	1.28	0.72	exceed the limit
ISO-W49	3.54	3.31	0.36	1.25	0.70	exceed the limit
ISO-W50	3.84	2.78	0.36	1.08	0.62	exceed the limit
ISO-W51	1.28	0.69	0.13	0.30	0.18	accepted
ISO-W52	2.43	2.17	0.45	1.22	0.71	exceed the limit
ISO-W53	3.18	2.54	0.33	1.13	0.64	exceed the limit
ISO-W54	2.96	2.61	0.50	1.38	0.80	exceed the limit
ISO-W55	3.06	2.83	0.64	1.70	0.99	exceed the limit

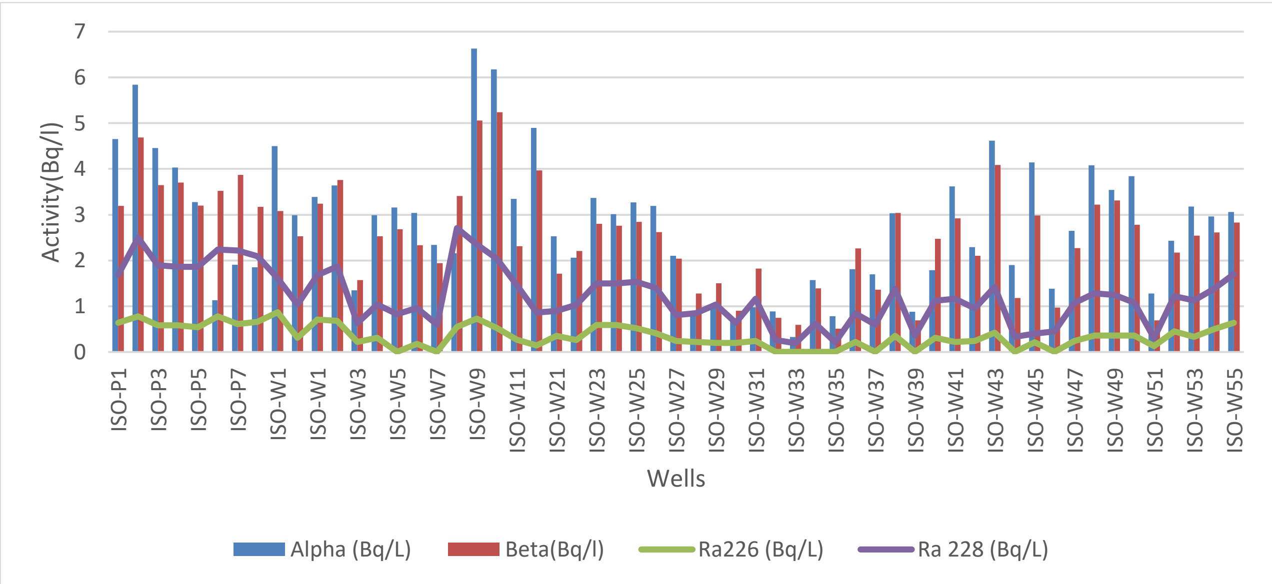


Fig #5 Comparison between radioactive indices through 2023-2024

LINE A	LINE D	LINE E	LINE G	LINE F	LINE C	LINE B	LINE H	LINE J	LINE K	LINE L	LINE M
P1	W28	W7	W38	W32	W21	W3	W41	W44	W48	W51	W53
P2	W29	W8	W39	W33	W22	W4	W42	W45	W49	W52	W54
P3	W30	W9	W40	W34	W23	W5	W43	W46	W50		W55
P4	W31	W10		W35	W24	W6		W47			
P5		W11		W36	W25						
P6		W12		W37	W26						
P7					W27						
P8											
W1											
W2											

Table # 3 analyzed wells names through 2023-2024

	Alpha (Bq/L)	Beta(Bq/l)	Ra226 (Bq/L)	Ra 228 (Bq/L)	DOSE
LINE A	3.53	3.58	0.67	1.98	1.14
LINE D	1.92	2.40	0.22	0.92	0.51
LINE E	4.26	3.66	0.44	1.67	0.93
LINE G	3.75	3.21	0.33	0.95	0.55
LINE F	1.85	1.98	0.22	0.55	0.32
LINE C	2.75	2.42	0.45	1.31	0.75
LINE B	3.06	2.51	0.25	0.94	0.52
LINE H	3.51	3.04	0.29	1.18	0.65
LINE J	2.52	1.85	0.23	0.56	0.33
LINE K	3.82	3.10	0.36	1.20	0.68
LINE L	1.86	1.43	0.29	0.76	0.44
LINE M	3.07	2.66	0.49	1.40	0.81

Table #4 indicates the higher dose achieved through the Disi wells (Line A) and the lowest dose (LineF&J)

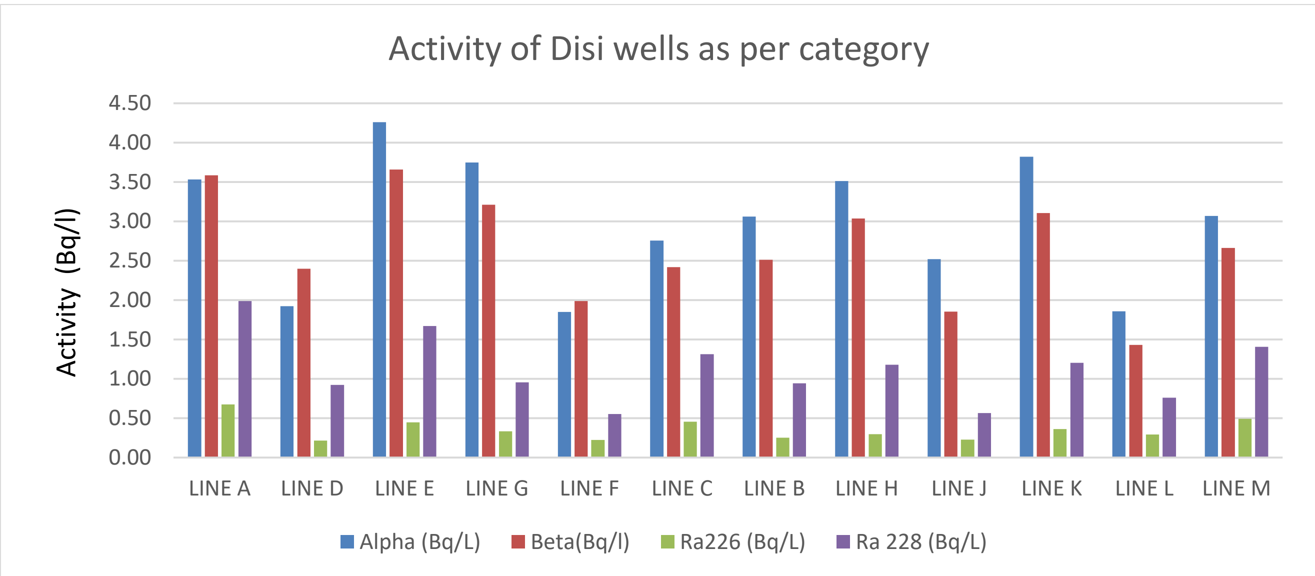


Fig.10 shows the Avg of the activity for Radium in the Disi wells asper categories

WELL NAME	Dose(msv/y)2023-2024	Dose(msv/y)2021-2022
ISO-P2	1.42	1.67
ISO-W33	0.12	0.18

Table #16 Max and Min AED for the measured well comparing with cycle 2021-2022 and 2023-2024

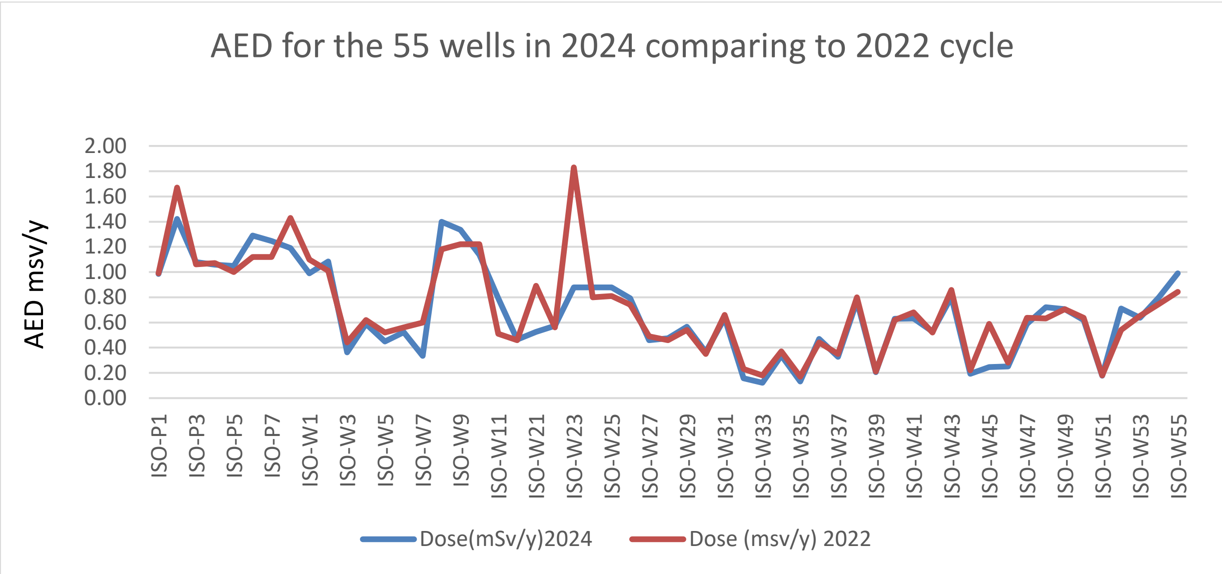


Fig #12 shows that there is consistency between AED through cycle 2022 and 2024 .

WELL NAME	Dose(mSv/y) 2024	Dose (msv/y) 2022
ISO-P1	0.98	0.99
ISO-P2	1.42	1.67
ISO-P3	1.08	1.06
ISO-P4	1.06	1.07
ISO-P5	1.05	1.00
ISO-P6	1.29	1.12
ISO-P7	1.25	1.12
ISO-P8	1.19	1.43
ISO-W1	0.99	1.10
ISO-W2	1.08	1.01
ISO-W3	0.36	0.44
ISO-W4	0.59	0.62
ISO-W5	0.45	0.52
ISO-W6	0.52	0.56
ISO-W7	0.33	0.60
ISO-W8	1.40	1.18
ISO-W9	1.34	1.22
ISO-W10	1.14	1.22
ISO-W11	0.79	0.51
ISO-W12	0.46	0.46
ISO-W21	0.53	0.89
ISO-W22	0.57	0.56
ISO-W23	0.88	1.83
ISO-W24	0.88	0.80
ISO-W25	0.88	0.81
ISO-W26	0.79	0.74
ISO-W27	0.46	0.49
ISO-W28	0.47	0.46
ISO-W29	0.57	0.54
ISO-W30	0.36	0.35
ISO-W31	0.63	0.66
ISO-W32	0.16	0.23
ISO-W33	0.12	0.18
ISO-W34	0.34	0.37
ISO-W35	0.13	0.17
ISO-W36	0.47	0.44
ISO-W37	0.33	0.35
ISO-W38	0.77	0.80
ISO-W39	0.21	0.21
ISO-W40	0.63	0.62
ISO-W41	0.63	0.68
ISO-W42	0.53	0.52
ISO-W43	0.80	0.86
ISO-W44	0.19	0.22
ISO-W45	0.24	0.59
ISO-W46	0.25	0.28
ISO-W47	0.59	0.64
ISO-W48	0.72	0.63
ISO-W49	0.70	0.71
ISO-W50	0.62	0.64
ISO-W51	0.18	0.18
ISO-W52	0.71	0.54
ISO-W53	0.64	0.65
ISO-W54	0.80	0.75
ISO-W55	0.99	0.84
MAX	1.42	1.83
MIN	0.12	0.17

Table #5 a comparison for the measured wells through 2022&2024

	Ra226 in Disi line	Ra228 in Disi line	AED in Disi line	Ra226 in Abu Alanda Res.	Ra228in Abu Alanda Res.	AED in Abu Alanda Res	Ra226 in Dabouk Booster Res.	Ra228 in Dabouk Booster Res.	AED inDabouk Booster Res	Ra226 in Shamisani Res.	Ra228 in Shamisani Res.	AED in Shamisani Res	Ra226 in Zatary Res.	Ra228 in Zatary Res.	AED in Zatary Res.
Month	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year
Jan	0.37	1.20	0.68	0.26	0.99	0.55	0.23	0.85	0.48	0.17	0.45	0.26			0.00
Feb	0.31	1.08	0.61	0.28	1.00	0.56	0.25	0.84	0.47	0.14	0.52	0.29			0.00
Mar	0.40	1.17	0.67	0.29	0.97	0.55	0.25	0.85	0.48	0.23	0.39	0.24			0.00
Apr	0.28	1.18	0.65	0.25	0.96	0.53	0.17	0.79	0.43	0.14	0.33	0.19			0.00
May	0.31	1.08	0.61	0.25	0.93	0.52	0.24	0.9	0.50	0.12	0.37	0.21			0.00
Jun	0.31	1.14	0.64	0.25	1.00	0.56	0.22	0.73	0.41	0.15	0.43	0.25			0.00
Jul	0.34	1.17	0.66	0.31	1.00	0.57	0.21	0.78	0.44	0.18	0.39	0.23	<0.12	<0.13	<0.50
Aug	0.36	1.23	0.69	0.31	1.08	0.61	0.24	0.81	0.46	0.17	0.56	0.32	<0.12	0.16	<0.50
Sep	0.35	1.23	0.69	0.29	0.99	0.56	0.27	0.78	0.45	0.17	0.47	0.27	<0.12	0.14	<0.50
Oct	0.34	1.27	0.71	0.25	0.87	0.49	0.23	0.77	0.44	0.21	0.46	0.27	<0.12	0.14	<0.50
Nov	0.34	1.23	0.69	0.26	0.83	0.47	0.24	0.81	0.46	0.21	0.52	0.30	<0.12	<0.13	<0.50
Dec	0.31	1.10	0.62	0.26	1.01	0.56	0.22	0.79	0.44	0.19	0.52	0.30			0.00
Avg	0.34	1.17	0.66	0.27	0.97	0.54	0.23	0.81	0.45	0.17	0.45	0.26	<0.12	0.15	<0.50

Table 8.a shows monthly radioactive indicators of the four delivery/blending points through 2023

	Ra226 in Disi line	**Ra228 in Disi line**	AED in Disi line	**Ra226 in Abu Alanda Res.**	**Ra228in Abu Alanda Res.**	Equivalent Dose in Abu Alanda Res	**Ra226 in Dabouk Booster Res.**	**Ra228 in Dabouk Booster Res.**	Equivalent Dose inDabouk Booster Res	**Ra226 in Shamisani Res.**	**Ra228 in Shamisani Res.**	Equivalent Dose in Shamisani Res
Month	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year	Bq/L	Bq/L	mS/year
Jan	0.32	1.13	**0.63**	0.30	1.04	**0.59**	0.21	0.78	**0.44**	0.16	0.38	**0.22**
Feb	0.35	1.23	**0.69**	0.26	1.08	**0.60**	0.19	0.76	**0.42**	0.20	0.46	**0.27**
Mar	**0.34**	**1.15**	**0.65**	**0.27**	**1.07**	**0.59**	**0.22**	**0.81**	**0.45**	**0.18**	**0.50**	**0.29**
Apr	0.32	1.30	**0.72**	0.23	0.98	**0.54**	0.20	0.81	**0.45**	0.16	0.43	**0.25**
May	0.38	1.18	**0.67**	0.31	1.05	**0.59**	0.23	0.77	**0.44**	0.16	0.34	**0.20**
Jun	0.34	1.18	**0.66**	0.26	1.11	**0.61**	0.22	0.84	**0.47**	0.18	0.60	**0.34**
Jul	0.45	1.12	**0.66**	0.34	1.07	**0.61**	0.25	0.78	**0.44**	0.17	0.45	**0.26**
Aug	0.32	1.20	**0.67**	0.29	1.13	**0.63**	0.24	0.77	**0.44**	0.15	0.43	**0.25**
Sep	0.30	1.16	**0.65**	0.26	1.00	**0.56**	0.21	0.78	**0.44**	0.16	0.57	**0.32**
Oct	0.34	1.09	**0.62**	0.25	1.01	**0.56**	0.23	0.77	**0.44**	0.16	0.51	**0.29**
Nov	0.35	1.26	**0.71**	0.24	0.94	**0.52**	0.23	0.87	**0.49**	0.2	0.53	**0.31**
Dec	0.44	1.23	**0.71**	0.27	0.98	**0.55**	0.35	0.83	**0.49**	0.26	0.54	**0.33**
Avg			0.67			**0.58**			**0.45**			0.28

Table 8.b shows monthly radioactive indicators of the four delivery/blending points through 2024

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