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The Uptake of Radionuclides by Some Fresh Water Aquatic Biota Review

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ABSTRACT

The work presented in this paper reviews many studies carried out by the authors along the last thirty years. The behaviour of the radionuclides in the aquatic ecology of Ismailia Canal stream is of great interest for the evaluation of the possible hazards that may occur to man through the movement of such radionuclides via food chain. Laboratory investigations have been carried out in order to understand the accumulation and release of some radionuclide by some aquatic biota (aquatic macrophytes aquatic plants, some snails species and some fish species) inhabiting this fresh water stream. Different parameters such as water pH, contact time, water salinity, etc. were used in these investigations. The kinetic analysis of the uptake process of some radio nuclides by certain biota was performed. From this analysis, it was possible (through the statistical methods) to investigate that the uptake process proceeded through different steps with different rates depending on the radionuclide and the biota species. It was possible to conclude that some of the selected biota can be used as biological indicators for certain radio nuclides.

Key words: Environmental, Aquatic biota, ^{60}Co, ^{89}Sr, ^{134}Cs, Uptake and retention.

INTRODUCTION

As the aquatic streams are composed of ; water, suspended matter, sediment and biota, each of these components plays an important role in the uptake and concentration of pollutants that may reach the water stream. These pollutants may be chemical biological or radioactive materials(1). The availability of the radionuclides to the aquatic biota depends largely on their chemical and physical forms and the rates and modes of their addition to the aquatic environment(2,3). The behaviour of the radionuclides in the aquatic environment is very complicated because of the large number of parameters which control their movement(4)),for the safety requirements, the knowledge of the aquatic environment behaviour assumes particular importance in relation to discharge of low level radioactive wastes. The diffusion of the radionuclides in the aquatic system occurs through several mechanisms and affected by many factors(5-7).

The rates at which radionuclides are accumulated by the fishes depend on both abiotic (e.g. temperature, salinity, water chemistry and pollution) as well as biotic factors e.g. ontogeny, phlogeny, population growth, diet, reproduction, physiology and migration(8-11). The intake of both natural and artificial radionuclides from non-marine food stuffs have been investigated in many studies(12-15). A calculation of the committed effective dose in the human body due to the consumption of a contaminated fish has been made(16-18). So it is necessary to collect as much information as possible on such mechanisms in order to assess the capacity of an aquatic environment to receive radionuclides without damage to the ecosystem. The work presented in this paper is a review of many studies carried out by the author about the uptake and the distribution of the radionuclides in some biota inhabiting Ismailia Canal ecology.

0EXPERIMENTAL

Various laboratory investigations were carried out to study the accumulation and release of the selected radionuclide by some biota, such as phytoplankton, aquatic plants, snails and fish. The experimental procedures necessary for investigating the accumulation and release of the biota can be summarized as follows.

The survey of the phytoplankton organisms present in the Ismailia Canal was carried out with the Sedgwick-Rafter method[19].The aquatic plants under investigation were ***Elodea densa, Ceratophyllum demersum, Potamogeton pictentus and Chara sp***. These aquatic macrophytes (plants) were collected from the Ismailia Canal fresh water stream. They were kept in large aquaria containing Ismailia Canal water and supplied with continuous aeration.

For the uptake studies they were immersed in aquaria containing contaminated solutions of various concentrations (from 0.5 to 10 µCi/l or 18.5 to 370 kBq/l) at pH 8.2. At predetermined intervals of time portions of these plants were removed and treated for radio assay. For release studies of the previously contaminated plants; the plants were immersed in aquaria containing fresh water that was changed frequently.

At predetermined intervals, plant samples were removed and treated for radio assay. Also the Water Hyacinth plant ***Eichhornia Cracippes*** was considered for investigating effect of contact time on the uptake and release of some radionuclides at concentration level ranged from 370 to 1110 kBq/l in filtered Ismailia Canal water.

Studies on the uptake and release of the radionuclides by the snails; ***Biomphalaria alexandrina*** and the bivalve calms ***Unio presidens*** were carried out under different experimental parameters. These snails were brought to the laboratory and kept in separate glass aquaria under continuous aeration and feeding for acclimatization to the laboratory conditions.

Tilapia zilli, Clarias lazera, Oreochromus Nilocicus and Cyprinus Carpio are fish of different species and of different morphologies were brought to the laboratory and kept with continuous feeding and aeration in glass aquaria for two weeks to be acclimatized to the laboratory conditions. Each kind of fish were kept in separate aquarium till the used in these investigations.

The radionuclides used in these investigations were solutions of; ^{32}P, ^{60}Co, ^{65}Zn, ^{89}Sr, ^{134}Cs and ^{144}Ce. The original solutions of the radionuclides were diluted in glass aquaria according the request of each experiment considered. The counting systems consist of a gamma ray spectrometer connected to a 3" well type NaI (Tl) scintillation detector for the γ-emitter radionuclides. In case of the β- emitter radionuclides G.M. detector connected to a single channel analyzer was used.

ANALYSIS OF THE DATA

The observed genera of the various phytoplanktonic groups(19) (i.e. ***Clorophyta-Cyanophyta, Dinoflagellata***, and ***Diatoms***) were recorded and the total number of organisms was calculated.

It was found that, during the spring season, the dominating organisms were ***Diatoms***. During the summer, there was a marked increase in the number of green algae (***Chlorophycae***) especially those representing the free-swimming and free-floating organisms. Generally, it can be possible to state that the phytoplankton present in Ismailia Canal water showed a variety of micro organisms, at a concentration varied from 150 to 300 organisms/ml of canal water (20)**.**

Aquatic Macrophytes

In general, it was noticed that the uptake of any the radionuclides under investigation by the aquatic macrophytes present in Ismailia Canal increased by increasing the initial concentration of the particular radionuclide in the aquaria from 18.50 to 370 kBq/l. The maximum uptake was reached by these plants after various period of contamination ranging from 1 to 4 days according to the type of the plant and the type of radionuclide(21).

A major portion, ranging from 45 to 85 % of the sorbed radionuclides, was released after 2 to 4 days when immersing the contaminated plant into fresh frequently changed water.

Examples of the uptake and release data by these aquatic plants are shown in Figs. (1and 2).

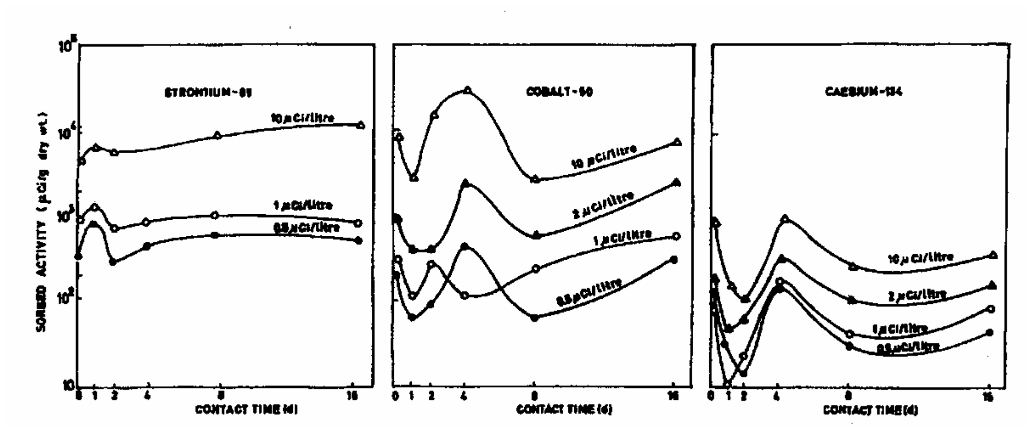
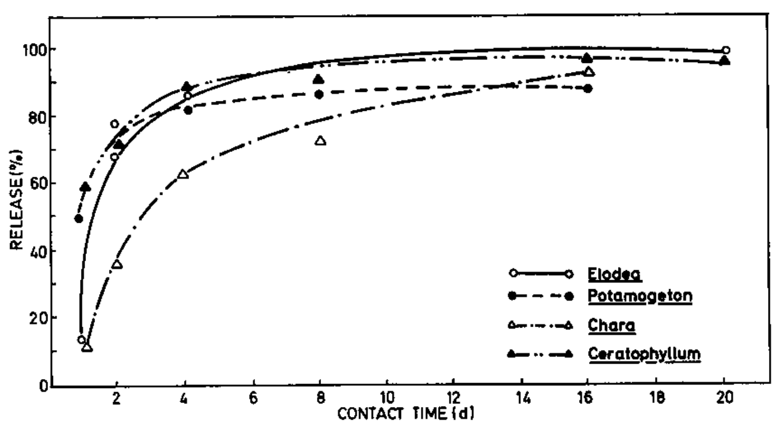


Fig (1) Uptake of radionuclides by Elodea densa plant.



Fig(2) : Release of strontium – 89 from different aquatic plants presents in Ismailia canal

The general picture indicated that there is a possibility of selection of certain plants in order to be considered as biological indicators for certain radionuclides. This means that they may give an indication about the contamination period and the corresponding concentration of such contamination in Ismailia Canal water.

It is always noticed during the experimental measurements that the concentration of the particular radionuclide in the aquarium remained constant, since the aquatic plants in the aquarium did not absorb after 16 days more than 1% of the total radioactivity. However, the experimental data derived from the uptake experiments using different radionuclides, led to the possible classification of these plants into two main groups. The first is that group in which the sorbed activity per gram dry weight increased proportionally by increasing the concentration of the radionuclide in water, while the second group included the plants which did not show significant correlation between sorbed activity of a particular radionuclide and its concentration in the surrounding water. This means that the first group could serve as a reliable biological indicator for the particular radionuclide.

In order to carry out this classification, statistical evaluations were made to test the significance of the correlation between the concentration of the radionuclide and its uptake by the aquatic plant at the different contamination periods. Significance tests of the linearity for each regression line passing the origin were made by computation of the samples regression coefficient and by the application of the "t" test values at the 95% confidence level[(22)]. This means that for "t" values less than 3.182, the regression line was considered significant at 95% confidence level for three degrees of freedom. Thus it is possible to select the following aquatic marophytes as they could serve as reliable biological indicators.

1. Ceratophyllum was found to be the most favourable biological indicator for the concentration of strontium radioisotopes in Ismailia Canal water range from 18.5 to 370 kBq/l, and for contamination periods up to 16 days.

2. Elodea was found to serve as a biological indicator for the strontium radioisotopes for contamination periods of 2 to 16 days.

3. Potamogeton was found to serve as a biological indicator for short periods of contamination by strontium and caesium radioisotopes (0.25 to 2 days) and for the phosphorus isotopes at period from 2 to 8 days.

4. Chara was found to serve as a biological indicator for cobalt isotopes only in so far the contamination period was 2 days only.

The Water Hyacinth Plant *Eichhornia Crassipes*

The Water Hyacinth plant ***Eichhornia Crassipes*** is a floating rooted fast growing fresh water aquatic plant. It causes problems to the water system. For the purpose of the uptake studies of the radionuclides by the plant, roots of similar shape and size plants and nearly of equal number of leaves were immersed in 1 litre aquaria containing 900 ml contaminated filtered Ismailia Canal water (FICW). The activity of the contaminated FICW in the glass aquaria was 370, 666, 740 1110 kBq/l of the radionuclides ^{60}Co, ^{144}Ce, ^{134}Cs and ^{65}Zn. Each radionuclide in separate aquaria. Samples from the leaves and roots in addition to water samples were taken at different intervals of time (from 1 to 16 days) and prepared for radio assay [(4, 23)].

Figs.(3-8) show the concentration factors (C.F.) for the leaves and roots as represented against contact time for the different radionuclides at the stated experimental FICW contamination levels. The C.Fs. increased with increase of the concentration of the contaminating radionuclide in the FICW (370–1110kBq/l) in non-linear relationships for most of the sampling time intervals. It has been observed that the C.Fs. increased with time within the experimental period for the roots and leaves for all the radionuclides used in this study. As a general trend it has been observed that the C.Fs. increased, in relation to contact time, in three distinct steps, differing according to the radioelement. From Figs**.(**3-8), it is clear that the uptake of the radionuclides by the plant roots is much greater than that of the leaves (more than 10^3 folds greater in some cases). The uptake of the radionuclides from the water stream by the Water Hyacinth plant is a complicated process. It depends upon many factors namely; climatic factors and water factors (mineral substances, organic substances ….etc.). Many theories were given in the explanation of this uptake process[(24)] from which an important factor for the uptake is the diffusion process of ions through the roots of the plant. The diffusion of the ions through the roots depends principally on the radius and charge of sorbed ions. Comparing the radii[(25)] of Zn^{++} 0.74 Å, Co^{++} 0.72 Å, Ce^{+++} Å 1.034 Å and Cs^{+} 1.67 Å) may give an explanation for the great difference in the C.Fs. values of these radionuclides in the plant roots. In this respect the charge of the sorbed ions plays also the principal role in the uptake process. In case of the plant leaves, the transport of the sorbed ions through the plant occur with more complicated process than that of the transport of the radionuclides from the contaminated FICW to the roots.

On the other hand, the data presented in this work showed that the % activity removed from the contaminated FICW were calculated and found to be about 90 to 94 % of the initial contamination activities of the studied radionuclides within the first day and perhaps within the first few hours of contact.

This phenomenon is very important in case of accidental radioactive releases to the water bodies, hence the Water Hyacinth plants can be dropped in the contaminated water body to act as a cheap decontaminating material and then the plants collected and considered as solid radioactive waste.

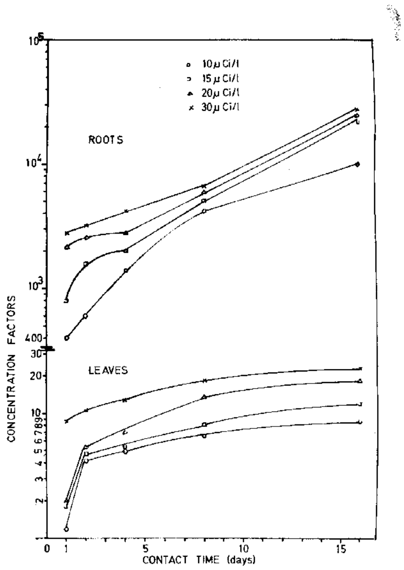


Fig (3): Uptake of Ce -144 by *Eichorina Crassipes* plant

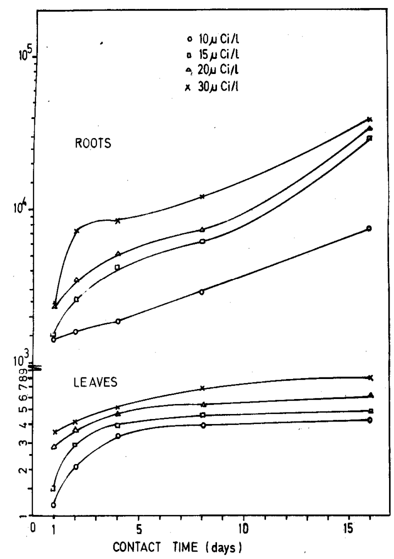


Fig (4): Uptake of Co – 60 by *Eichorina Crassipes* plant

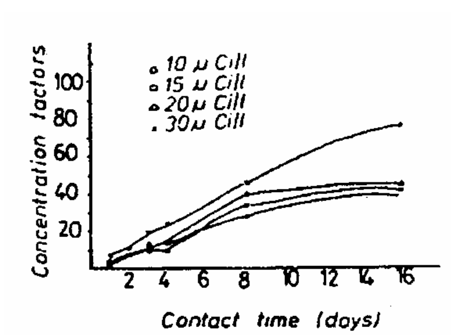


Fig (5) : Effect of contact time on the uptake of Cs-134 by the leaves of the water Hyacinth Plant.

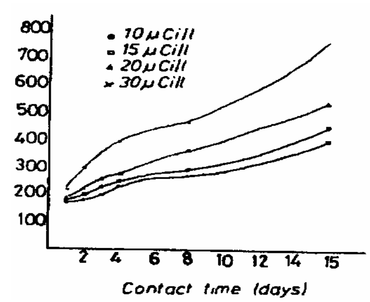
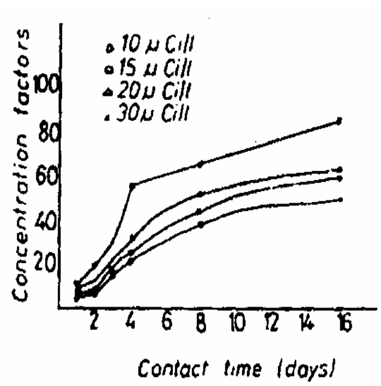


Fig (6) : Effect of contact time on the uptake of Cs-134 by the roots of the water Hyacinth Plant.



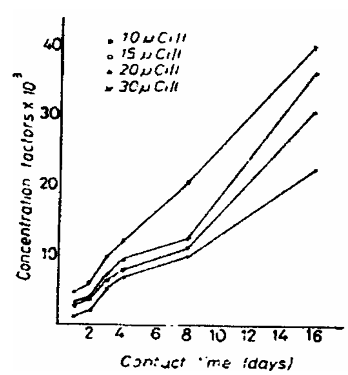
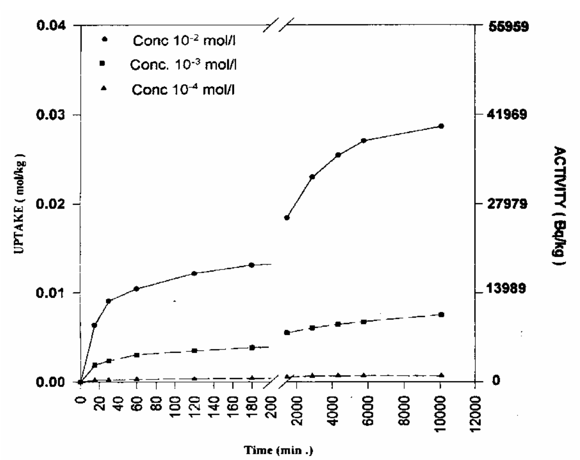


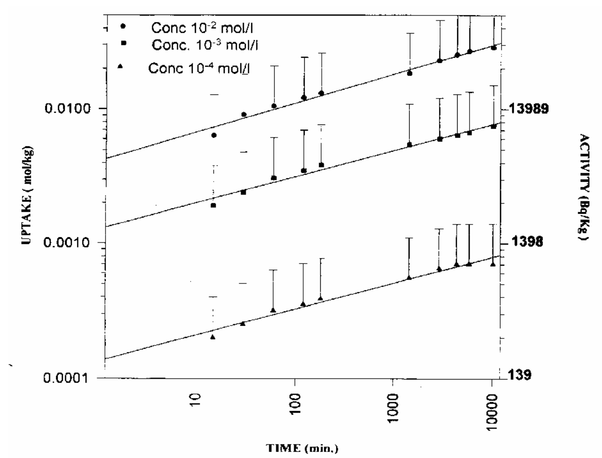
Fig (7) : Effect of contact time on the uptake of Zn – 65 by the leaves of the Water Hyacinth Plant.

Fig (8) : Effect of contact time on the uptake of Zn – 65 by the roots of the Water Hyacinth Plant.

The general picture of the uptake of the studied radionuclides by the Water Hyacinth plant indicated that there is a possibility of using this plant as biological indicator. In order to establish this statement, statistical evaluation were made to test the significance of the correlation of the isotope concentration (from 370 to 1110 kBq/l) in the FICW and the uptake of these radionuclides by the aquatic plant at each time interval of sampling (from 1 to 16 days). Thus, calculations for the **"t"**[(26)] values at 95% confidence level for three degrees of freedom were made. From the obtained results it may be possible to state that Water Hyacinth ***Eichhornia Crassipes*** plant can serve as biological indicator for ^{134}Cs during the period from 1 to 4 days, for ^{65}Zn during the period from 3 to 8 days, for ^{144}Ce in the first 2 days while it serve for ^{60}Co at 1,2 and 4 days.

Studied of different parameters affecting the uptake of ^{60}Co by the Water Hyacinth plant such as ; contact time, Co^{++} ions concentration, water pH and other competing ions. It was found that the plant roots concentrated the Co^{++} ions much more than its bulb and leaves as previously given by other authors[(4,23)]. As cobalt concentration increased from 10^{-4} to 10^{-2} M., the uptake by the whole plant increased with time as shown in Fig (9). These data when plotted on a logarithmic scale showed a linear relation ship between the uptake and time as shown in Fig (10).





Fig(9) **Fig(10)**

Fraction uptake by the whole plant at different carrier concentrations

As the uptake data were treated statistically by the compartmental method of analysis [(28)], it was found that the uptake of Co^{++} ions process proceeded in a two or more step reactions. These uptake steps are represented by the general equation

$$C=C_1e^{-k_1 t} + C_2 e^{-k_2 t} + C_3 e^{-k_3 t} \ldots\ldots\ldots + C_n e^{-k_n t}$$

Where C_1, C2, C3…..C_n are the remaining cobalt activity (concentration) in the aqueous phase at zero time for each reaction step and k_1, k_2, k_3 …..k_n is the reaction rate constants for each phase.

The half life $T_{1/2}$ of each step can be calculated from the known equation $T_{1/2} = 0.693/k$

It was shown[(27)] that the uptake process of $^{60}Co^{++}$ by the aquatic plant proceeded in a three step reactions as the concentration of Co^{++} in FICW was 10^{-2} and 10^{-3} M., while it proceeded in two steps only as the cobalt concentration decreased to 10^{-4} M. The equations of these uptake steps are given below;

For 10^{-4} M Co^{++} concentration

$$C = 0.2442e^{-0.0038t} + 1.8392e^{-0.0003t}$$

$k_1 = -0.0038$ $k_2 = -0.0003$

$T_{1/2} = 2.96$ hr $T_{1/2} = 38.5$ hr.

For 10^{-3} M Co^{++} concentration

$$C = 0.1438e^{-0.0038} + 0.1931e^{-0.0004t} + 1.662e^{-0.00003118t}$$

$k_1 = -0.0038$ $k_2 = -0.0004$ $k_3 = -0.00003118$

$T_{1/2} = 3.04$ hr $T_{1/2} = 28.88$ hr $T_{1/2} = 319.79$ hr.

For 10^{-2} M Co^{++} concentration

$$C = 0.0377e^{-0.0003t} + 0.044\,e^{-0.000012t} + 1.9086e^{-0.000001t}$$

$k_1 = -0.0003$ $k_2 = -0.000012$ $k_3 = -0.000001$

$T_{1/2} = 38.5$ hr $T_{1/2} = 1155$ hr $T_{1/2} = 7219$ hr

As the pH of the FICW contaminated with the radioactive Co^{++} ions increased from 5 to 9 the uptake of Co^{++} ion by the whole plane decreased.

Also the effect of different competing ions (Na^{+}, Sr^{++} and Al^{+++}) concentrations (from 10^{-4} to 10^{-2} M with Co^{++} 10^{-3}M in solution) decreased the uptake of the Co^{++} by the whole plant variably. The valency and the concentration of the competing ions in the FICW affected greatly the decreasing effect on the uptake process of cobalt by the plant.

Snails

1) Biomphalaria alexandrina

Data were given by some authors(29) from the study on the uptake and release of (^{134}Cs, ^{89}Sr and ^{60}Co) by the invertebrate fresh water snails; ***Biomphalaria alexandrina***. They found that ***B. alexandrina*** continuously accumulated these radionuclides (with contact time till three weeks with the contaminated water).

They found that the affinity of these snails was much greater for ^{60}Co than ^{89}Sr and ^{134}Cs as shown in Figs.(11&12). This led others to make a more comprehensive study on the uptake of ^{60}Co by these snails. They studied different parameter affecting the uptake of ^{60}Co by these snails such as contact time, pH, carrier concentration, and competing ions.

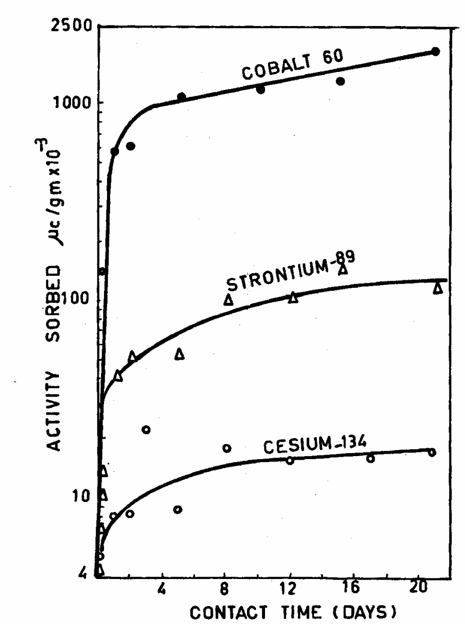
They were able to analyze the uptake data of Co^{++} as a function of time according the compartmental method(29) and concluded that the uptake process proceeded in three steps with different rates of uptake as shown in Table (1)

Table (1) Uptake Equations of Cobalt by the Snails *B.Alexandrina*

Sol.Conc. M/L	Uptake Equation
10^{-4}	$C = 0.0769e^{-0.0028t} + 0.0368e^{-0.0003t} + 1.8669e^{-0.0000021t}$
10^{-3}	$C = 0.0905e^{-0.00151t} + 0.0905e^{-0.0002t} + 1.8857e^{-0.0000025t}$
10^{-2}	$C = 0.0355e^{-0.0014t} + 0.007e^{-0.0000035t} + 1.93e^{-0.00000052t}$

Changing the pH of the contaminated solution from 5 to 9 increased the uptake of cobalt by the snails ***B. alexandrina***. They noted that there was a rapid increase of uptake as the pH increased from 5 to 9 (about 33 time greater). This rapid increase was considered as precipitation of the cobalt ion as $Co(OH)_2$ on the snails shells and not due to uptake at this pH.

Furthermore, as the concentrations of the competing cations (Na^{+}, Ca^{++}, Sr^{++} and Al^{+++}) in the contaminated solution were increased from 10^{-4} to 10^{-2} M/l, the uptake of ^{60}Co by the snails was reduced in different amounts according to the competing cations presence concentrations and their valencies.



Fig(11):Sorption of radionuclides by the snail *Biomphalaria Alexandrina* in radioactive tap water

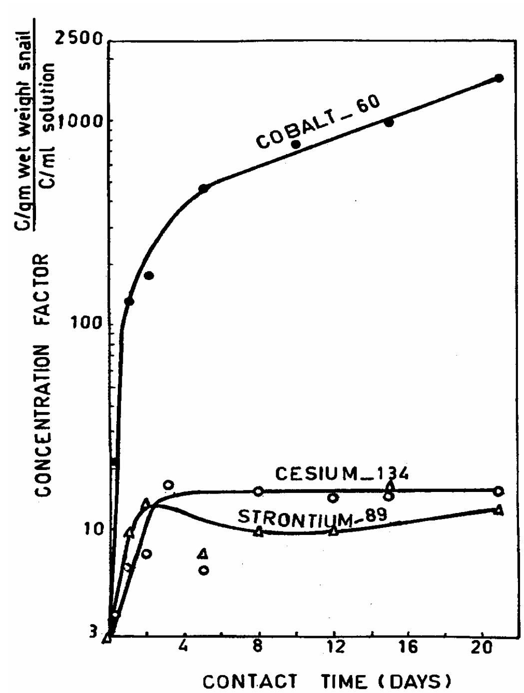


Fig (12): Concentration factors of radionuclides by the snail *Biomphalaria Alexandrina* in radioactive tap water.

2) The bivalve clam *Unio Presidens*

Some other authors[(5)] studied different parameters affecting the uptake of ^{60}Co. ^{144}Ce and ^{65}Zn by the soft tissues and shells of the bivalve clam Unio presidens. The activity levels used in this work were 370 kBq/L for the studied radionuclides each in separate aquarium. As the contact time between the clam and the contaminated FICW (from 0.25 to 5 days), the concentration factors (C.F.'s.) of the clam soft tissues increased from 0.18 to 42.28, 2.96 to30.74 and 2.90 to 10.15 for the radionuclides ^{60}Co, ^{144}Ce, and ^{65}Zn respectively. As shown in table (2) the accumulated activity (kBq/g dry weight) increased with a rapid rate in the first day interval. It has been observed that the accumulated activity by this type of snails was much greater for ^{60}Co > ^{65}Zn > ^{144}Ce. These data showed an agreement with the work presented by other authors[(30)] on ***Biomphalaria alexandrina*** snails which showed higher uptake of ^{60}Co than ^{89}Sr and ^{134}Cs. The fluctuation of the bioaccumulated activity for both soft tissues and shells of the clam may be attributed to both the difference in the metabolic character of the clam towards the studied radionuclides and their chemical characteristics.

As the carrier concentration of each of the studied radionuclides increased from 20 to 400 ppm, both the C.F.' s and the bioaccumulation activity by this snail decreased for both soft part and shell. As the carrier concentration in the medium of the experiment increased from 20 to 400 ppm, the ratios of the C.F.'s and the A.A for soft part and shell changed respectively **for ^{60}Co**: 21.86 to 34.24 and from 22.33 to 33.78 ; **for ^{144}Ce**: 8.78 to 4.96 and from 15.80 to 1.67 and **for ^{65}Zn** : 18.77 to 22.74 and from 32.88 to 22,27.

In general, the observed decrease in the uptake by the snail ***Unio Presidens*** with increase of carrier concentration may be attributed to a metabolic character of the clam itself. This effect of increasing carrier concentration on the uptake has been observed by other investigators [27, 31].

As the pH of the contaminated FICW increased from 5 to 9, the C.F.'s and A.A. increased up to pH 7 then fall down. This decrease may be due to the increase of the $(OH)^-$ ions in the medium which constitutes a stress on the clam leading to a decrease in the assimilation of the studied radionuclides[32]. Also the formation of the colloidal hydroxides of cobalt and cerium at pH higher than 7 may have a role in decreasing the uptake process. The low values of the C.F' s and the A.A. for the shell may be related to the low metabolic process. This phenomenon had been also reached by another worker[27] on effect of pH on the uptake of ^{60}Co by the snails ***B.alexandrina***.

As the size of clam increased from 1.5 to 6 grams the uptake of the radionuclides decreased which may be explained by the fact that the metabolic rate as well as assimilation rate of small size clam is greater than that of other sizes. It is worth mentioning that this phenomenon was observed in both soft part and shell.

The authors were able to state that this kind of snails can be used as biological indicator for the radionuclides ^{60}Co, ^{144}Ce and ^{65}Zn. This statement was emphasized by the statistical evaluations to test the correlation of the C.F.'s ratios of the soft part to shell uptake and the carrier concentration. Calculations of the "t" values at 95% confidence level for five degrees of freedom were made. The results are significant for five degrees of freedom at 95% confidence level at "t" values less than 2.02. From the obtained results, it may be possible to state that this clam can be used as biological indicator for ^{60}Co, ^{144}Ce and ^{65}Zn whenever they reached the canal water within the range of 370 kBq/l.

Table (2): The Bioaccumulation of ^{60}Co, ^{144}Ce and ^{65}Zn (kBq/g) by the snail *Unio Presidens*

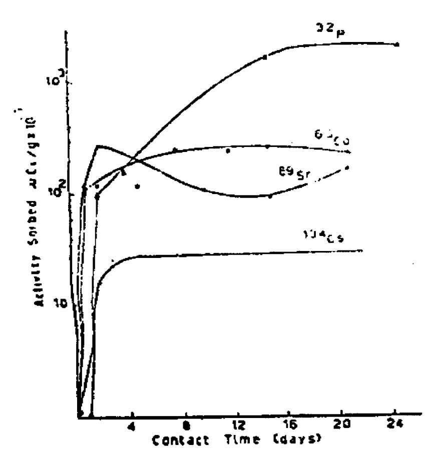
Isotope	Contact time	Soft part	Shell
Cobalt-60	0.25 (d.)	0.445	0.679
	1	14.979	2.514
	2	118.349	3.275
	5	180.771	4.372
Cerium- 144	0.25	0.128	0.116
	1	0.228	0.176
	2	1.697	0.349
	5	0.751	0.534
Zinc-65	0.25	11.540	0.488
	1	18.993	1.147
	2	26.079	2.875
	5	63.079	4.368

Fish

Tilapia zilli fish

In the study[32] of the uptake of ^{134}Cs, ^{89}Sr, ^{60}Co and ^{32}P by the ***Tilapia zilli*** fingerling fish**,** showed that the accumulated activity increased rapidly within the first two days then almost increase slightly till 15 days. ^{89}Sr showed a decrease after two days reaching its minimum at the 15th day then increased thereafter. On the other hand, ^{32}P showed continuous increase till the 15th day followed by slow rate of e uptake thereafter. From these data, as shown in Fig.(13) it is obvious that the ***Tilapia zilli*** fish accumulated the studied radionuclides in the following order : ^{32}P > ^{60}Co > ^{89}Sr > ^{134}Cs .

The release of the radionuclides from this fish as placing the contaminated fish in frequently changed tap water, it was observed from Fig.(14) that ^{89}Sr was tightly fixed to the fish since only not more than 10% of the sorbed activity were released after one month contact. On the other hand, the fish released not more than 90% of its sorbed ^{134}Cs activity and not more than 80% of its ^{89}Sr uptake.



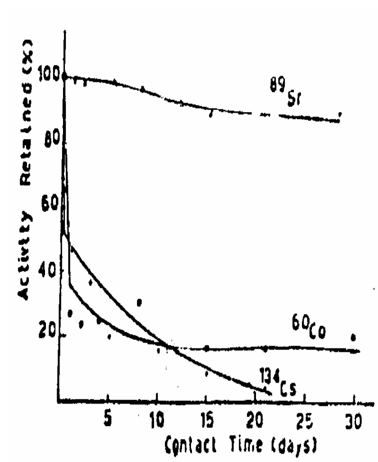


Fig (13) ; Sorption of radionuclides by *Tilapia Zillii* Fish in radioactive tap water.

Fig (14) : Release of activity from Contaminated *Tilapia Zillii* fish in frequently changed tap water.

Clarias lazera fish

Some authors(33,34) studied the uptake and distribution of ^{32}P, ^{89}Sr, ^{134}Cs and ^{60}Co in the different organs and tissues of the *Clarias lazera* fish via ingestion(18.5 kBq) or by direct uptake from contaminated FICW (at level of about 370 kBq/l

Muscles tissues retained the highest percent(after 15 days) of ^{134}Cs from the administered dose and from direct uptake from the contaminated FICW followed by bone and other organs. Heart and spleen showed the lowest activity retained in the fish.

As the distribution of ^{60}Co by the same fish tissues and organs via the two modes of uptake. The bone tissues retained the highest percentage activity followed by muscles and gills. The heart and spleen showed the lowest ^{60}Co percentage activity retained.

In case of ^{32}P; showed some differences in the distribution of ^{32}P in the tissues with the two modes of uptake. Intestine retained the highest ^{32}P level of activity followed by stomach and bone with the lowest level of retained activity in heart and spleen in case of ingestion. Meanwhile bone tissues showed highest % ^{32}P retained as the direct uptake from contaminated water.

For ^{89}Sr as it was expected, the bone tissues showed the highest % ^{89}Sr retained by the ***Clarias lazera*** fish while heart and spleen showed the lowest % ^{89}Sr activity retained by the two modes of uptake.

Table (3) shows a comparison of the percentage retained of the studied radionuclides in the different tissues and organs of the ***Clarias lazera*** fish after 15 days via ingestion and by direct uptake from contaminated water.

Table (3) Percent Accumulated Activity of ^{134}Cs, ^{60}Co, ^{32}P and ^{89}Sr by *Clarias lazera* Fish after 15 Days of Uptake via Ingestion and from Contaminated FICW

Tissue or organ	^{134}Cs		^{60}Co		^{32}P		^{89}Sr	
	Ingested	Water	Ingested	Water	Ingested	Water	Ingested	Water
Muscle	41.73	45.75	30.07	20.98	22.48	3.20	9.98	7.45
Bone	28.27	27.44	45.13	42.32	43.69	13.75	67.57	70.00
Gills	7.96	8.00	6.56	20.69	13.65	4.02	20.10	19.59
Stomach	7.95	5,47	1.68	3.68	3.02	22.65	1.75	0.89
Intestine	4,96	3.44	5.27	5.83	8.75	54.83	1.75	0.86
Liver	3.83	3.76	4.76	2.95	4.38	0.92	0.00	0.65
Kidneys	2.37	3.91	5.58	2.93	2.66	0.51	0.24	0.70
Spleen	0.68	0.48	1.14	0.14	0.88	0.04	0.36	0.05
Heart	------	1.08	----	0.48	0.51	0.08	-----	0.13

Another author(35) made similar studies on the uptake and distribution of ^{60}Co and ^{65}Zn in the whole fish and those tissues. It has been observed that the whole fish and its organs accumulated ^{65}Zn to a higher extent than ^{60}Co. This may be attributed to the greater demand of fish and its organs to the Zn^{++} ions than that for the Co^{++}. This was emphasized as the data showed that the A.A. decreased by the whole fish and its organs as the carrier concentration increased from 5 to 20 ppm in case of ^{65}Zn whereas it decreased in the same direction in case of ^{60}Co. It has also be noted that A.A. values of ^{60}Co are being of lower values than that reported by other fresh water fish**(36,37)**. Also the same author(36) showed that the uptake of both radionuclides decreased as the pH of the medium increased from pH 5 to pH 7.

To the above data another author(38) applied statistical analysis on the uptake data as a function of time using the compartmental method of analysis and was able to state that the uptake process for both ^{65}Zn and ^{60}Co proceeded in three steps of reactions. The 1st rapid one (few minutes or hours) representing the assimilation and excretion, with different rates of uptake. The 2nd and 3rd steps are of slower rates for both radionuclides.. The parameters of the uptake equations for ^{65}Zn and ^{60}Co are given in Table (4).

Other authors(39,40) made studies on the uptake and release of ^{85}Sr and ^{134}Cs by ***Clarias lazera*** fish separate or mixed together in the same aquarium. The statistical analysis of the uptake data of both radionuclides by the fish revealed three steps of uptake in case of ^{85}Sr and two steps in case of ^{134}Cs. The equations of uptake steps , the calculated reaction rate constants and the half-life of each uptake step are tabulated in Table (5).

It was also shown(41) that the distribution the A.A. of the ^{85}Sr within the tissues of the fish in the order; Bone > gills > liver > muscles whereas, the distribution of ^{134}Cs followed the order liver > gills > muscle > bone .

As the carrier concentration increased from 10^{-5} to 10^{-3} M in case of both strontium and caesium, the A.A. decreased for all the studied organs without effect on the order of distribution in the organs. Increasing the Ca^{++} ions concentration in the FICW from 10^{-5} to 10^{-3} M, decreased the ^{85}Sr A.A. for the different organs, while increasing the increasing Cs^{+} ions concentration in the strontium medium, by the same amount, did not show significant changes in the A.A. values.

As the K^+ ions concentration increased in the ^{134}Cs aquarium by the same increasing decrements, the ^{134}Cs A.A. by the fish organs decreased. In the same time increasing Ca^{++} ion in the ^{134}Cs aquarium did not show significant effect on the uptake by the different organs of the fish.

Table (4) The numerical parameters of the Uptake Steps of ^{65}Zn and ^{60}Co by the *Clarias lazera* Fish

Radionuclides		Step 1	Step 2	Step 3
Zinc- 65	**Equation**	$Y_1= 1.1709e^{-0.5792t}$	$Y_2= 0.7247e^{-0.0382t}$	$Y_3= 1.8917e^{-0.0323t}$
	A	1.1709	0.7247	1.1817
	k	- 0.5792	- 0.0382	- 0.0323
	$T_{1/2}$ hr	1.196 .	18.14	21.46
Cobalt-60	**Equation**	$Y_1= 1.110e^{-1.5294t}$	$Y_2 = 0.6771e^{-0.0528t}$	$Y_3 = 1.9137e^{-0.0528t}$
	A	1.110	0.6771	1.9137
	k	- 1.5294	0.0528	0.0528
	$T_{1/2}$ hr	0.45	13.13	13.13

Table (5) The numerical values of the uptake of ^{85}Sr and ^{134}Cs steps by the *Clarias lazera* fish

Radionuclides		Step 1	Step 2	Step 3
Sr -85	**Equation**	$Y_1= 0.0484e^{-0.0432t}$	$Y_2=0.0303e^{-0.0064t}$	$Y_3=1.9156e^{-0.0009t}$
	A	0.0484	0.0303	1.9156
	k	- 0.0432	- 0.0064	- 0.0009
	$T_{1/2}$(hr)	16.02	108.28	770.00
Cs-134	**Equation**	$Y_1= 0{,}037e^{-0.0786t}$	$Y_2= 1.9606e^{-0.003t}$	
	A	0.037	1.9606	
	k	0.0786	0.003	
	$T_{1/2}$(hr)	8.82	223.55	

Oreochromis Nilocicus and Cyprinus Carpio fish

Another authors(3,41) studied the uptake retention of ^{65}Zn and ^{60}Co by two fresh water fish species; ***Oreochromis Nilocicus*** and ***Cyprinus Carpio*** using initial contaminating activity (ICA) ranged from 74 to 740 kBq/l. For all the ICA the uptake by both fish species increased with contact time. It was observed that at the different time intervals the uptake of $^{65}Zn > ^{60}Co$ for the bone, flesh and viscera tissues of both fish. On the other hand, they found that after 12 days contact with fresh water most of the cobalt activity retained by the bone tissues. A comparison of retention of cobalt and zinc it was found that:: the % retained by the bone for $^{60}Co > ^{65}Zn$, the % retained by the flesh for $^{65}Zn > ^{60}Co$ and the % retained by the viscera for $^{60}Co > ^{65}Zn$. It was possible to state that the ***Oreochromis Nilocicus*** fish retained more ^{60}Co than the ***Cyprinus Carpio*** fish. This may be attributed to the behaviour of each fish and to the variation in the morphology and chemical composition of the two fish species. This differences could also be due to the relatively higher biological demand for cobalt by the ***Oreochromis Nilocicus*** fish.

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