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Vermiremediation of Heavy Metal Contaminated Soil

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***Abstract*—Soils contaminated with heavy metals pose a high risk to ecosystem health. In this project earthworms were used for the remediation of heavy metal. Heavy metal contaminated soil was collected from petroleum pump, cherpulassery. Soil organic matter content, soil type, soil moisture content, soil temperature, soil pH are most critical factors that frequently regulate the earthworm population. From the results, we can say that earthworms can remove heavy metals such as, arsenic, cadmium, chromium, nickel, lead, zinc, mercury, copper to a particular limit.**

Index Terms*—- *Soil, Contamination, Heavy Metals, Earthworms

I. INTRODUCTION

Due to industrialization our ecosystem is polluting day by day. Use of several types of chemicals and toxic products for different purposes will also affect the health. Soils contaminated with heavy metals pose a high risk to ecosystem health because of the multiple toxic effects associated with these chemicals at very low concentrations. Release of heavy metals into soil is also toxic even they are at very low concentrations. And heavy metals are not only cytotoxic, but also carcinogenic and mutagenic in nature. In this developed world, there are several techniques to remove heavy metals such as chemical precipitation, oxidation, reduction, filtration, ion exchange etc. but most of these techniques became ineffective, when the concentration of heavy metals are less than 100 mg/l. At this stage we can use microorganisms and plants for the removal of contaminants. In bioremediation process we use microorganisms and their biodegradative capacity to remove contaminants. In this project earthworms were used to remove heavy metals. So this process is known as vermiremediation.

A. Environmental Factors affecting earthworm's population

Several environmental factors affect activity, population density, abundance and distribution of earthworms. Soil organic matter content, soil type, soil moisture content, soil temperature, soil pH are most critical factors that frequently regulate the earthworm population.

B. Organic matter

Organic matter is the major food source of earthworms. Many researchers found a positive correlation between soil organic matter content and earthworm number and biomass. A soil with low organic matter content cannot support higher number of earthworms[7]. The quality of organic residues is also important affecting the earthworm abundance and diversity. Generally earthworms do not prefer residues with high C:N ratio owing to their lower palatability.

C. Soil type

The soil environments in which earthworms inhabit affect their abundance and distribution. Soil texture affects earthworm populations since it influences other soil properties like moisture, nutrients [7]. Higher numbers of earthworms are found in light and medium loam soil than in heavy clay, sandy and alluvial soils

D. Moisture

Earthworms generally require adequate moisture for their proper growth and development. Water constitutes about 75-90% body weight of earthworms. They respire through a moist skin and the blood capillaries on the surface should get enough moisture to perform respiratory activity. Earthworm activity is determined by adequately available soil moisture. Earthworm's activities are higher in moist soil than in dry soil and thus protection against desiccation is required. The moisture requirement varies among species and different regions of the world. Earthworms adopted different strategies to cope with dry soil conditions. Some move to lower soil layers, some diapause and some produce drought resistant cocoons. For growth and development of earthworms 60-70% moisture is optimum. Adequate moisture accompanied with heavy rainfall is fatal to earthworms. Because excessive moisture takes the place of dissolved oxygen and creates anaerobic conditions, earthworms are forced to move to the soil surface where they are subjected to damaging by ultra-violet radiation and predation.

E. Temperature

Temperature greatly affects the growth, metabolism, activity, reproduction and respiration of earthworms. Higher temperatures above the critical limit for survival can kill earthworms. Cold and moist conditions can be better tolerated by earthworms than hot and dry conditions [7]. Temperature tolerances and preferences of earthworms vary from species to species. Temperature also affects fecundity, duration of cocoon incubation time and the growth period from hatching to sexual maturity in earthworms. Cocoons tend to hatch sooner at higher temperature. 10-15 ^{0}C is the optimal temperature for growth of the indigenous population of Lumbricidae in Europe. In night soil temperature not exceeding 10.5 ^{0} C is the most suitable condition for earthworm activities.

F. Soil pH

Earthworms are very sensitive to soil pH. Abundance, distribution and species composition of earthworms are affected by soil pH. A neutral soil pH is preferred by most species of the earthworms, but pH of 5.0 to 8.0 can be tolerated by them. Low or high pH is generally unfavourable for many species of earthworms and increase or decrease in soil pH may cause decline in earthworm count [7].

II.METHODOLOGY

Soil sample used to find out the heavy metal concentration (such as, zinc, copper, mercury, lead etc) is collected from a surface near petroleum pump, Ayyappankaavu, Cherpulassery. Due to the leakage of petroleum tank, this soil was contaminated with heavy metals. Top soil not exceeding a depth of five inches after clearing the vegetation cover was dug with a shovel and about 5kg of soil was collected from there.

Fig 1: place from which soil sample collected to find out the heavy metal concentration

The earthworms needed for the experiment was mainly collected from my own house. Mainly earthworms are present in soil which has moisture content. The earthworms were washed with water.

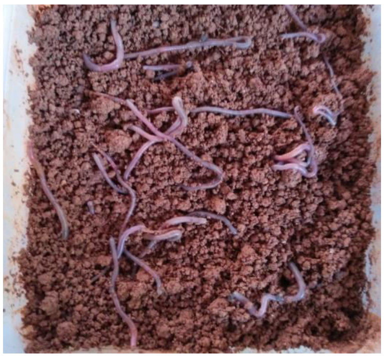

Fig 2: Earthworms Used For the Experiment

A. Determination of changes in heavy metal concentration

Three rectangular containers with cover lid and clips on both sides of the edges measuring 20 x 9 x 12 cm were purchased from the market. The containers were weighed with a Digital Sensitive Weighing balance and were properly labeled using tape and a permanent marker. 1 kg of the contaminated soil was then weighed into each of the 3 containers and were moistened with distilled water to the water holding capacity of the soil. After 3 days, cow dung was freshly collected and about 50 g each of the cow dung weighed was thoroughly mixed into the containers with contaminated soil. Immediately after the addition of additives, earthworms were sorted out of the holding containers, washed with clean water and ten earthworms were inoculated into the contaminated soil. A netting material cut into sizes was placed on top of each of the containers and the cover lid frame was placed on top of it to hold it firmly with the help of the clips on both sides of the containers. This is done to avoid escape of the earthworms and allow free flow of oxygen into the treatments. The setup was placed in a shady area and checked morning and evening on a daily basis. . After 15,30 and 45 days the samples were collected from each container and the heavy metal concentration were find out using IS-3025 methods.

Fig 3: Experimental Setup for the Determination of Changes in Heavy Metal Concentration

B. Determination of effect of heavy metal content in vermiremediation process

To find out the effect of concentration of petroleum oil, 1 kg of the sun-dried soil was then weighed into each of the three containers. With a glass beaker, 5ml of crude oil was thoroughly mixed, into each of the three containers having 1 kg each of soil and were moistened with distilled water to the water holding capacity of the soil. The treatments with crude oil contaminated soil were left to stay for 3 days. After 3 days, cow dung was freshly collected and about 50 g each of the cow dung weighed was thoroughly mixed into the containers with crude oil-contaminated soil. Immediately after the addition of additives, earthworms were sorted out of the holding containers, washed with clean water and ten earthworms were inoculated into the crude oil contaminated soil. A netting material cut into sizes was placed on top of each of the containers and the cover lid frame was placed on top of it to hold it firmly with the help of the clips on both sides of the containers. This is done to avoid escape of the earthworms and allow free flow of oxygen into the treatments. The setup was placed in a shady area and checked morning and evening on a daily basis. After 15,30 and 45 days the samples were collected from each container and the heavy metal concentration were find out using IS-3025 methods.

Fig 4: Experimental Setup for the Determination of Effect Of heavy metal Content In vermiremediation

III. RESULTS AND DISCUSSIONS

A. Determination of Changes in Heavy Metal Concentration

From table we can see that initially, some heavy metals arsenic, lead, cadmium, zinc, mercury are not in limit. After the vermiremediation of 45 days, all the heavy metals in soil were came in limit

Heavy Metal	Changes In Heavy Metal Concentration(mg/kg)				% Of Reduction After 45 Days	Limits (mg/kg)
	Initial	15 Days	30 Days	45 Days		
Arsenic	12	3	0	0	100	1-50
Cadmium	0.3	0.19	0.12	0.03	90	0.01-0.7
Chromium	109	77	46	14	87.15	1-1000
Lead	67	51	29	9	86.56	2-200
Mercury	0.07	0.04	0.01	0	100	0.01-0.3
Nickel	87	64	36	11	87.35	5-500
Zinc	110	87	54	27	75.45	10-300
Copper	24	19	15	3	87.5	2-100

TABLE 1 CHANGES IN HEAVY METAL CONCENTRATION DURING VERMIREMEDIATION

The concentration of arsenic, cadmium, chromium, lead, mercury, nickel, zinc and copper were reduced as 76.92%, 95.5 %, 81.2 %, 54.46 %, 63.3 %, 61.31 %, 82.07 % and 85.18 % respectively

B. Determination of Effect of heavy metal Content In Vermiremediation

To determine the effect of heavy metal concentration in vermiremediation, 5, 10, 15 and 20ml of petrol is added into soil. And the experiment is repeated. The results are tabulated below:

TABLE 2
CHANGES IN HEAVY METAL CONCENTRATION DURING VERMIREMEDIATION, WHEN 5ML OF PETROL IS ADDED INTO SOIL

Heavy Metal	Changes In Heavy Metal Concentration(mg/kg)				% Of Reduction After 45 Days	Limits (mg/kg)
	Initial	15 Days	30 Days	45 Days		
Arsenic	52	39	26	12	76.92	1-50
Cadmium	0.9	0.6	0.09	0.04	95.5	0.01-0.7
Chromium	596	409	287	112	81.2	1-1000
Lead	213	176	125	97	54.46	2-200
Mercury	0.3	0.22	0.19	0.11	63.3	0.01-0.3
Nickel	274	217	164	106	61.31	5-500
Zinc	318	227	126	57	82.07	10-300
Copper	81	56	34	12	85.18	2-100

TABLE 3
CHANGES IN HEAVY METAL CONCENTRATION DURING VERMIREMEDIATION, WHEN 10ML OF PETROL IS ADDED INTO SOIL

Heavy Metal	Changes In Heavy Metal Concentration(mg/kg)				% Of Reduction After 45 Days	Limits (mg/kg)
	Initial	15 Days	30 Days	45 Days		
Arsenic	27	16	9	2	92.59	1-50
Cadmium	0.5	0.2	0.09	0.03	94	0.01-0.7
Chromium	315	238	147	67	78.73	1-1000
Lead	135	113	73	21	84.4	2-200
Mercury	0.12	0.1	0.07	0.03	75	0.01-0.3
Nickel	147	107	67	17	88.43	5-500
Zinc	237	174	99	29	87.76	10-300
Copper	47	32	18	5	89.36	2-100

Heavy Metal	Changes In Heavy Metal Concentration(mg/kg)				% Of Reduction After 45 Days	Limits (mg/kg)
	Initial	15 Days	30 Days	45 Days		
Arsenic	44	27	16	6	86.36	1-50
Cadmium	0.8	0.51	0.24	0.07	91.25	0.01-0.7
Chromium	567	334	138	76	86.59	1-1000
Lead	196	134	82	29	85.28	2-200
Mercury	0.25	0.19	0.08	0.03	88	0.01-0.3
Nickel	214	137	87	27	87.38	5-500
Zinc	318	236	115	34	89.3	10-300
Copper	67	48	29	12	82.08	2-100

TABLE 4
CHANGES IN HEAVY METAL CONCENTRATION DURING VERMIREMEDIATION, WHEN 15ML OF PETROL IS ADDED INTO SOIL

TABLE 5
CHANGES IN HEAVY METAL CONCENTRATION DURING VERMIREMEDIATION, WHEN 20ML OF PETROL IS ADDED INTO SOIL

Heavy Metal	Changes In Heavy Metal Concentration(mg/kg)				% Of Reduction After 45 Days	Limits (mg/kg)
	Initial	15 Days	30 Days	45 Days		
Arsenic	65	59	37	26	60	1-50
Cadmium	1.1	0.6	0.58	0.44	60	0.01-0.7
Chromium	718	545	434	416	42.06	1-1000
Lead	267	198	174	137	48.68	2-200
Mercury	0.3	0.28	0.21	0.17	43.33	0.01-0.3
Nickel	375	340	197	118	68.53	5-500
Zinc	417	338	296	265	36.45	10-300
Copper	98	78	67	59	39.79	2-100

From the tables we can see that the heavy metal concentration decreases with time. And when the heavy metal content is high, the remediation process become slow, the remediation percentage decreased.

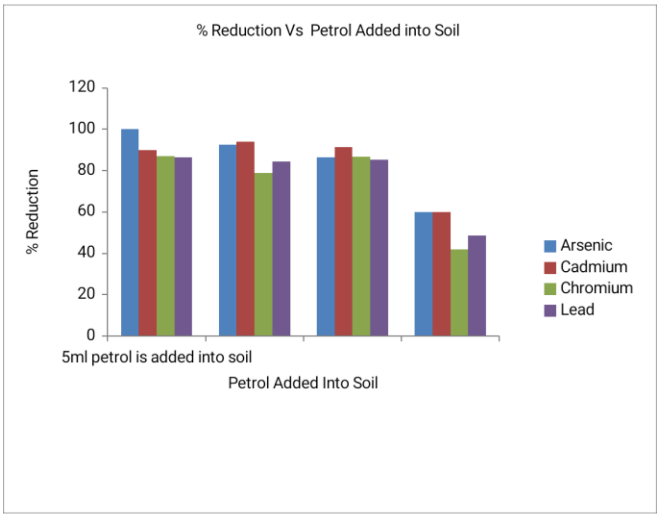

Fig 5(a): Graph Showing % Reduction of Heavy Metal Concentration after 45 Days Vermiremediation

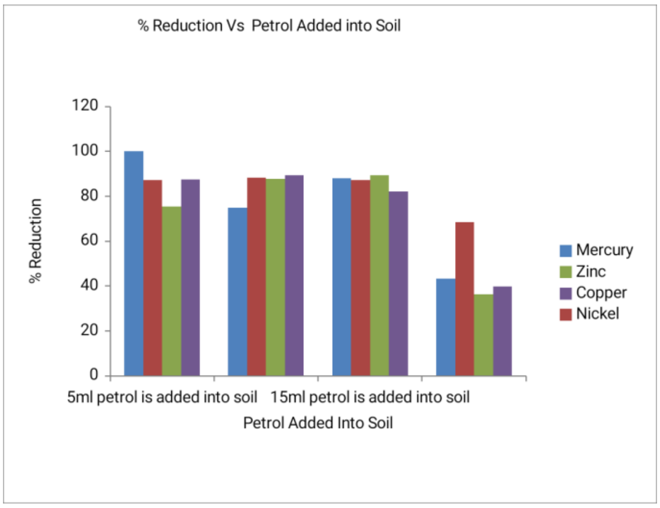

Fig 5(b): Graph Showing % Reduction of Heavy Metal Concentration after 45 Days Vermiremediation

From the graph we can see that in case of all the heavy metals, there is a large reduction in concentration. We can note that when heavy metal concentration increases the efficiency of vermiremediation decreases. When we add 20 ml of petrol into soil, the heavy metal concentration increased and the vermiremediation decreased. So we can summerise that the efficiency of earthworms in remediation process decreases, when the heavy metal content increases.

IV. CONCLUSIONS

Earthworms play an important role to improve soil fertility in a variety of ways. Earthworms are also known as farmer's friend. Soil organic matter content, soil type, soil moisture content, soil temperature, soil pH are most critical factors that frequently regulate the earthworm population. From the results, we can conclude that earthworms can remove heavy metal to a particular limit.When heavy metal concentration increases the vermiremediation decreases. When we add 20 ml of petrol into soil, the heavy metal concentration increased and the vermiremediation decreased. So we can summarise that the efficiency of earthworms in remediation process decreases, when the heavy metal content increases.So we can provide earthworms in places where the soil is contaminated with heavy metal(As, Cd, Cr, Ni, Pb, Zn, Hg,Cu). Care should be taken to add nutrients, which is used by earthworms for their survival. For example, we can provide a barrier in the contaminated site, where earthworms can be introduced. The barrier is provided to avoid the escape of earthworms from the contaminated site. And the size of the barrier is depended on the heavy metal concentration.

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