Use Of Electromagnetic Energy In Removal Of Phenole Compounds From The Municipal Wastewater

*M. Al- Ani **Wisam J. Al-Hilo ***Firas R. Al-Khalidy

Date of acceptance 12/2/2006

Abstract

Due to the importance of wastewater treatments and the urgent need for these processes, constructing treatment plants to get optimum efficiency of treating using alternative methods instead of conventional one is required.

Most modern methods of treatment of wastewater are using radiation as a new technology in observation and the treatment of municipal wastewater. For these reasons radiation is used as a method in the treatment of industrial and municipal wastewater. This study involves the removal of phenol concentrations from the treated municipal wastewater.

Gamma radiation (most powerful radiation in penetrating materials) is used in the removal of the phenol from the wastewater samples taken from the effluent of sedimentation tank of AL-Rustamia wastewater treatment plant.

Doses of radiation are used, such as 25, 50, 100, 200, 300, 400 and 500 krad. The final value is an average of the three samples for the same absorbing dose of radiation. Most of the measurements are found in the acceptable range of Iraqi limits of these tests.

Phenolic samples were the most sensitive to the radiation, the values reach an acceptable concentration within the Iraqi limits of 0.01 – 0.05 mg/l. and the concentrations reach 0.0121, 0.0192 and 0.041 mg/l at 500 krad.

Introduction

Humans look to new features to solve the environmental problems, especially in the field of water pollution, due to many reasons [1]: -

1. The quantity of water on earth is fixed and, in most part, fresh water is in a constant state of recycle.
2. Among the large number of different types of users of water, there are already many who must take extraordinary steps to further treat the so-called "fresh water" because of the inability of our three principal treatment opportunities to remove all contaminants. Those three principle treatment opportunities are:-

a- The wastewater treatment facilities, which release water to the open environment.

b- The natural treatment provided by the open environment.

c- The "fresh water" treatment facilities retaking the water from the open environment.

The rapid growth in the world population, and the intensive development of various industries all over the world led to very basic environmental problems. The worldwide application of fertilizers, pesticides, etc., in modern agriculture and disposal of large amount of chemical waste materials to rivers,

* Prof. Dr. College of Engineering University of Al-Mustansiria
**School of Applied Science University of Technology
*** College of Engineering University of Al-Mustansiria

seas, and oceans has led to heavy pollution of water resources. The disinfection of drinking water (containing humic substances) by chlorination has contributed further in this respect by causing the formation of mono-, di-, tri-halomethanes, as well as halogenated phenols. In addition, the reduction due to chlorination of microorganisms in wastewater treatment plant was found to be insufficient, [2].

RADIATION TREATMENT:

Radiation treatment may be defined as the application of ionizing radiation energy to produce a useful change in a material, such as disinfection. The amount of radiation energy absorbed in a material depends on both the chemical and physical state of the material and the type and energy distribution of the radiation. Radiation dose units are the rad (100 erg/g) [1] and the gray (1 Gy = 1J/kg) [2]. For biological comparison the respective units are the rem[3] and the sievert (sv) which present the physical dose unit multiplied by a radiation quality factor (QF). For biological effectiveness the yield may be expressed as a D_X value, where D10 is the dose needed to reduce a population by a factor of ten. The application of radiation energy to water and wastewater treatment needs to achieve a sufficient dose absorbed uniformly at a given flow rate and an economic yield. The factors involved include the type of radiation; its energy distribution, the penetrability into the water stream, the geometric of the radiation-water interaction volume and the thickness of water normal to the radiation flux [1, 5]

GAMMA RADIATION: Gamma ray, emitted during the decay of radioactive atoms, which is electromagnetic radiation, has relatively high penetrating power. The two radioisotopes used most often for industrial application are 60Co and 137Cs. Cobalt-60 emits two gamma rays with energy of 1.17 and 1.33 MeV per decay. The 60Co source decays with a half-life of 5.26 years. Cesium-137 emits one gamma ray of 0.66 MeV per decay, but with a half-life of 30 years. The intensity of a gamma ray source determines the exposure time for a given dosage. Some factors such as the source-to-water geometry, the percent of solids in the water affecting the bulk density and irradiator design. For sludge treatment, the amount of wet sludge to be irradiated depends on the percent solids to which the water is de-watered [5].

LITERATURE REVIEW

Since the discovery of radiation, many applications and studies have been developed using different types of radiation. Some of these applications are harmful for humanity and the other are not. Among the harmful uses are the nuclear and atomic bombs, waste hazards, development of cancer and other diseases due to ionizing radiation. Yet among the peaceful uses are treatment of cancerous diseases cases, nondestructive testing, polymerization, tracer technique and the subject of this study i.e. treatment of wastewater.

The fact that ionizing radiation produces biological damage has been known for many years. The first case of human injury was reported in the literature just a few months following Roentgen's original paper in 1895 announcing the discovery of x-ray. As early as 1902, the first case of x-ray induced cancer was reported in the literature.

A result of exposure to radiation in large amount existed in the 1920s and 1930s based upon the experience of early radiologists, miner exposed to underground airborne radioactivity, persons working in the radium industry, and other special occupational groups. The large term biological significance of smaller, chronic doses of radiation, however, was not widely appreciated until the 1950s and most of our current knowledge of the biological effects of radiation has been accumulated since World War II, [3].

Studies carried out at 1988 and 1992 showed that there have been many plants of wastewater treatment and disinfection in the world that use irradiation facilities, such as Geiselbullach, Germany that served 240,000 people. Deer Island, Boston, USA of discharge 100,000 gal/d (373.5 m3/d) and the plant of radiation disinfection in Japan, which discharge 3000 m3/d and served 600,000 people [4],

Degradation of Phenol Takehtsa, M., Sakumoto, A. [6] showed that the initial G-values of phenol (G-phenol) decomposition in dilute aqueous solution are 2.7 in oxygenated solution and 0.45 in de-aerated solution. G-(phenol) in oxygenated solution is very close to that of G-OH, probably because the OH-radical reacts rapidly with phenol to form dihydroxy cyclohexadienyl radical $C_6H_5(OH)_2$, also that shows clearly the effect of ionizing radiation on phenol concentration , the phenol decomposition only depends on total dose and not on water flow rate and beam current in the range studied. The dose phenol decomposition curve is similar to that obtained by the gamma radiation.

It is concluded that oxidative treatment can be carried out with the use of electron beam at the same radiation chemical efficiency as with gamma ray in properly designed reactor for oxygen dissolved.

A special dose rate effect is found in oxygen deficient solution for phenol decomposition, the molar ratio of oxidized products analyzed by liquid chromatography to the decrement of phenol at an initial stage of the reaction by electron beam and gamma irradiation. The ratio of the detected products to the phenol decrement in the first column decreases from 0.96 to 0.08 with the decreases in oxygen concentration by electron beam irradiation. However, the ratio is 1.0 and 0.53, respectively, in oxygenated and de-aerated solution by gamma irradiation. Under a high dose rate irradiation intermediate radicals tend to recombine with each other to be a dimeric product in competition with peroxyradical formation through a reaction of the radical with oxygen.

Machi and co-workers [9] showed that, the distribution of phenol has been studied as a function of carbonate concentration. It is well known that phenol reacts rapidly with the hydroxyl radicals (reaction rate = 6.6 × 109 rec./mol.s), and that the hydroxyl radicals are scavenged by carbonate. A comparison of the decomposition kinetics of phenol as a function of absorbed dose at pH 5 and pH 7.

Study objective is to use the radiation as a new technology in the removal of the phenol from the raw wastewater and determining the optimum doses of radiation in the treatment

Materials And Methods

Sampling:-

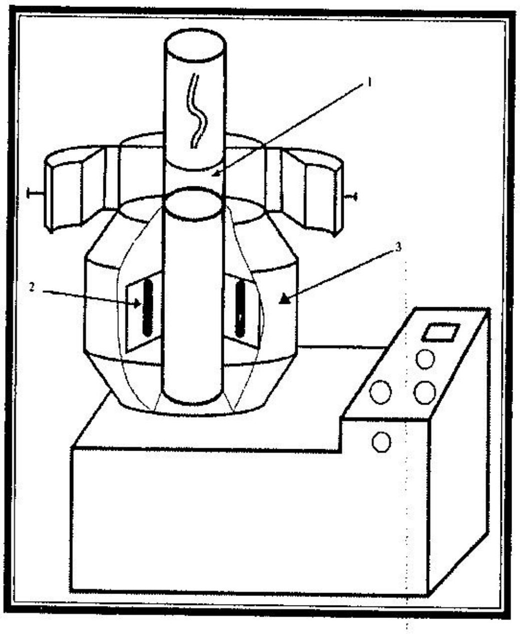
Samples of wastewater were collected from AL-Rustamia sewage treatment plant for three months January, February and March. The samples were collected by using glass bottles of 2.5 L.

The samples are taken from the effluent of the primary settling tank by holding the bottle, or the container in the opposite direction to the water flow then its mouth is opened until filled with water then closed. The samples are kept in ice chest then they are transported immediately to the laboratory within short time.

Irradiation:-

The facility used in irradiation is Gamma-cell 220 (Canadian made) supplied with 60Co which has a calculated dose rate of 2 Mrad/hr and radioactivity of 50 kCi at January 1985.

Samples are arranged in the chamber of irradiation which is of cylindrical geometry of 16 cm in diameter and 20 cm in height. This room moves vertically down to the radiation sources of ^{60}Co as roods rotate around the room to supply a homogenous dose for all samples, as in Fig (1) [7].



1- Irradiation room.
2- Rood of ^{60}Co.
3- Surrounding shields of lead.

FIG (1) Gamma cell irradiation facility type 220 Canadian made (Japan Atomic Energy Research Institute, Takasaki, Japan, 1982). [7].

ABSORBING DOSE

All tests in this study are taken as an average of three samples subjected to the same absorbing dose. The doses used are 0, 10, 25, 50, 100, 200, 300, 400, and 500 krad. The dose rate in recent time (i.e. 2002) is approximately 0.2 Mrad/hr (Calculated on the basis that the half-life of 60Co is 5.26 years). The irradiation times for these dosages are 0, 3, 7.5, 15, 30, 60, 90, 120, and 150 min. respectively where: -

D = DR x T

D = Absorbing dose, (rad).
DR = Dose Rate, (rad/min.).
T = Irradiation time, (min.).

The samples after irradiation are transported to the laboratory as soon as possible for testing.

PHENOLIC COMPOUNDS

Phenol is a group of aromatic organic compounds, which are highly toxic to living organisms. They can poison sewage treatment system and taint water in very small concentration. Phenol can be found in industrial and some municipal wastes and it may cause taste and odor.

If chlorine is present, phenol should be limited to less than 0.001 ppm in drinking water. The samples of phenol are extracted by chloroform then distilled to get a clear solution which is measured by the use of UV-Visible spectrophotometer type **SHIMADZU CORPORATION model UV- 160A made in Japan**.

The wavelength used to the determination of phenol concentration is indicated by the use of spectrometric test by UV-meter for sample with blank, as shown in Fig (2) and table (1). The wavelength is indicated more specifically by the decrease in the range of spectrometry, as shown in Fig (3) and table (2). From both figures and tables, the wave length usage is 510 nm, then the test is done by using standard fit line, as shown in Fig (4), to measure final concentration of phenol.

RESULTS AND DISCUSSION

The ionizing radiation has a drastic effect on the organic materials in the wastewater, because of the strong activity of gamma radiation energy that changes the characteristic of pollutants in the wastewater [5].

Table (3) and Fig (5) below show the results of the radiation in the three months samples.

Most of the results are found to be in the accepted ranges (0.01-0.05 mg/l) according to the Iraqi allowable values of conventional concentrations that can be disposed to the surface water [8].

The phenol concentration values are determined for the analysis of samples, it is found that all these values at final absorbing dose of radiation are in accepted range. They vary from 8.4% of their initial value in January, 6.2%, for February and 13.16% for March. The decrease in the concentration of phenol matches very well with the results of Takehtsa & Sakumoto [6] also that is clear in the result of Machi [9]. The degradation of phenol samples never reaches zero concentration value because the samples of wastewater contain a series of different types of phenol such as chlorophenols and nitrophenols and these compounds are very surfactant chemical agents [6].

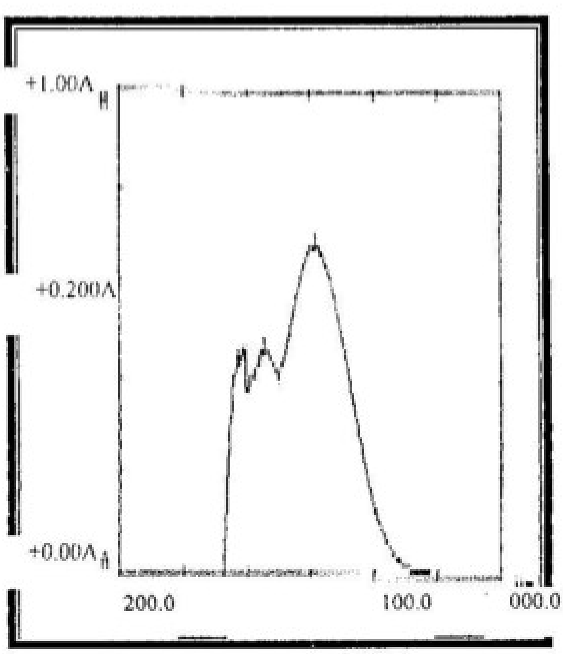


FIG. (2) Spectrum of phenol sample.

TABLE (1) Values of absorbance at characteristic wave lengths of phenol sample for figure (Japan Atomic Energy Research Institute, Takasaki, Japan, 1982). (6).

*** PEAK-PICK ***			
-- PEAK--		--VALLEY—	
λ	ABS	λ	ABS
507.0	0.679	449.0	0.415
426.0	0.464	301.0	1.639

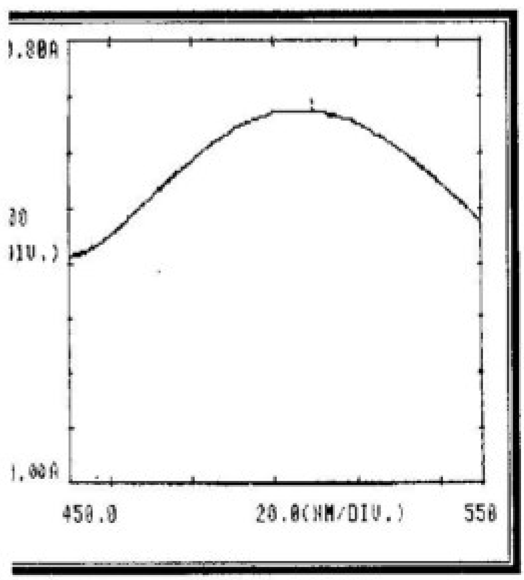


FIG (3) Short range of the spectrum of phenol sample.

TABLE (2) Values of absorbance at characteristic wave lengths of phenol sample for figure. (Japan Atomic Energy Research Institute, Takasaki, Japan, 1982). [7].

*** PEAK-PICK ***			
-- PEAK--		--VALLEY—	
λ	ABS	λ	ABS
509.4	0.675		

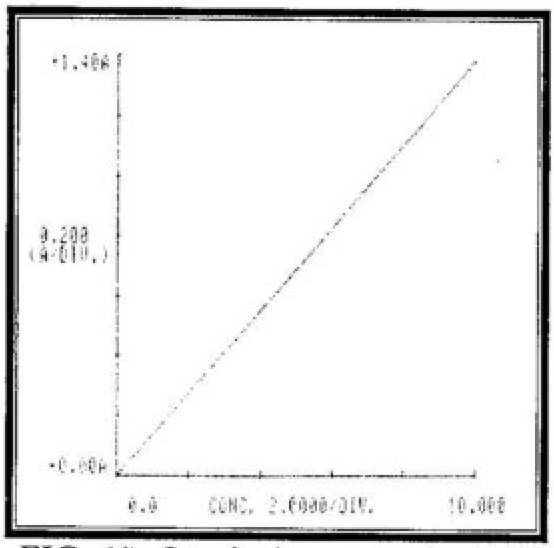


FIG (4) Standard curve of phenol determination.

TABLE (3) Laboratory analyses of Phenols measurement for January, February and March.

Dose (krad)	Phenols (mg/l)		
	January	February	March
0	0.1449	0.3115	0.3091
10	0.1274	0.25	0.2615
25	0.1195	0.1315	0.2063
50	0.0903	0.1021	0.1232
100	0.0582	0.0931	0.0961
200	0.0391	0.0723	0.0721
300	0.0302	0.0502	0.0532
400	0.0263	0.0231	0.0522
500	0.0121	0.0192	0.041

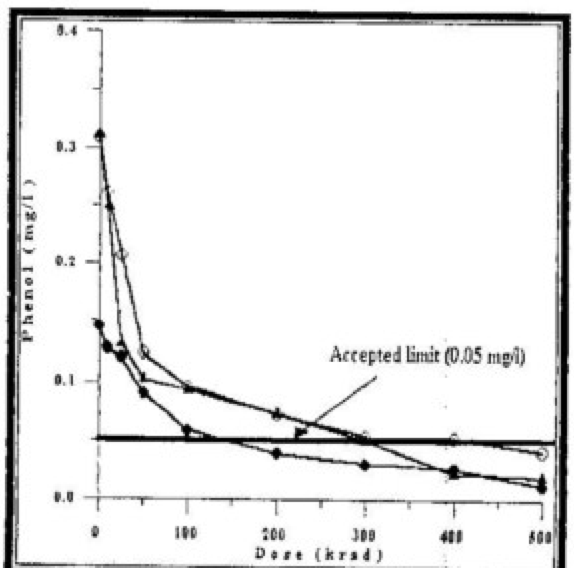


FIG. (5) Phenol concentration of irradiated sample of wastewater for ●- January, ▲- February and o – March

Conclusions And Recmmendations

Conclusions: -

1 . The present study shows the possibility of a significant increase in the phenol decomposition yield in wastewater. The low dose rate, high concentration and presence of oxygen are conditions under which the chain reaction occurs, and results in high decomposition yield up to several hundreds. However inorganic ions terminate the chain reaction.

2 . Irradiation by gamma radiation is an efficient physical way to destroy organic compounds, as long as the radiation parameters delivered are correctly suited to the application. Under the experimental conditions, the optimal doses were mentioned in table (3), even at these values the radiation efficiency for most parameters is, surprising, and not completely satisfactory.

3 . Irradiation procedure involves one of the most important parameters to get continuous operation, which is the continuous aeration by using air or oxygen injection to the irradiation chamber.

Recommendations:-

1. The efficiency of treatment will be increased if the combined process of treatment is applied. Using combined process of irradiation and even heat, ozone, aeration, or ultraviolet ray can carry that out.

2. Conventional wastewater treatment plants receive many types of surfactant pollutants such as pesticides, linear alkyl sulfonates, toxic materials and others. Irradiation process could be tested in the evaluation of its efficiency in treating these pollutants.

3. Although the average person is subjected to diagnostic and/or therapeutic radiation several times in his life, he does not understand the

radiation mechanisms. The designers of wastewater irradiators must necessarily convey the processes of the plant and its safeguards in an information program; what is implicit to the plant designers must become explicit to the public.

REFERENCES

[1].IAEA, 1975 "***Radiation for a clean environment***", Vienna,.

[2].GAY, H. G., Wilson, B. K., SWINWOOD, J. F. ,(1988) "***Gamma radiation Processing of wastes an introduction, Beta Gamma"***, John Wiley & Sons, Ltd., New YorkPp (21–27).

[3].MAKENIE, L. DAVIS, DAVID, A., CDRNWELL", 1991 ***Introduction to environmental engineering***", McGraw Hill Inc., New York,.

[4].MACHI, 1988. S., "***Treatment of supernatant from sludge, by combination of EB irradiation and biological treatment"***, John Wiley & Sons, Ltd., Toronto "

[5].IAEA, 1992. " ***Application of isotopes and radiation in conservation of environment***", Vienna,

[6].TAKEHTSA, M, SAKUMOTO, A. (1982). "***Radiation treatment of wastewate***r" Takasaki radiation chemistry research establishment, Japan Atomic Energy Research Institute, Takasaki, Japan,

[7].Atomic Energy of Canada ., (1984). "*Certification 42 of measurement gamma cell 220 No.200*", John Wiley & Sons, Ltd., Toronto

[٨].سعاد عبد عباوي، محمد سليمان حسن، (١٩٩٠). الهندسة العملية للبيئة (فحوصات الماء)

[9].MACHI, S., ARAI, H.," 1988 ***Wastewater treatment by electron beam and gamma rays Use of high energy electron for treatment of water and waste water*** ",(Pioc. NSF Siminar – workshop Miami,).

استخدام الطاقة الكهرومغناطيسية في ازالة مركبات الفينول من المياه الثقيلة المحلية

محمد العاني* وسام جاسم الحلو** فراس رزاق الخالدي***

* كلية الهندسة/ الجامعة المستنصرية

** قسم العلوم التطبيقية/الجامعة التكنولوجية

*** كلية الهندسة/ الجامعة المستنصرية

الخلاصة

نظرا لاهمية معالجة المياه الثقيلة ، والحاجة الماسة لها فقد انشأت معامل للمعالجة من اجل الحصول على امثل كفاءة للمعالجة باستخدام طرائق بديلة عوضا عن الطرائق التقليدية .

معظم الطرائق الحديثة في معالجة المياه الثقيلة تستخدم التشعيع كتقنية جديدة في مراقبة ومعالجة المياه الثقيلة. لهذا فان التشعيع يستخدم كطريقة في معالجة المياه الثقيلة الصناعية والمحلية .

هذه الدراسة تتضمن ازالة تراكيز الفينول من المياه الثقيلة المحلية المعالجة . حيث استخدمت اشعة كاما (وهي اشعه قوية شائعة في اختراق المعادن) في ازالة الفينول من نماذج المياه الثقيلة الماخوذة من ترسبات جريان المياه في خزانات موقع المعالجة في الرستمية جنوب بغداد .

استخدمت عدة جرعات من الاشعة ، هي : (٢٥ ، ٥٠ ، ١٠٠ ، ٢٠٠ ، ٣٠٠ ، ٤٠٠ ، ٥٠٠) كيلوراد. القيمة النهائية هي متوسط لثلاث عينات لنفس جرعة الاشعة الممتصة . وقد وجد ان معظم القياسات هي ضمن المدى المقبول للحدود المسموح بها في العراق لهذه الفحوصات.

اظهرت قياسات عينات الفينول بان معظمها حساسة للاشعة وان القيم لاتتجاوز حدود التراكيز المقبولة في الحدود العراقية المسموح بها (٠,٠١ ـــ ٠,٠٥) ملغم / لتر حيث ظهرت التراكيزفي هذه الدراسة كما يأتي: (٠,٠١٢١ ، ٠,٠١٩٢ ، ٠,٠٤١٠) ملغم/ لتر في ٥٠٠ كيلوراد.