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Applying Tracer Techniques to NPP Liquid Effluents to Estimate Maximum Soluble Pollutants in a Manmade Channel

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Abstract
Tritium routinely released as low activity liquid radioactive waste by Cernavoda Nuclear Power Plant was used as a radiotracer to study longitudinal dispersion of Danube Black Sea Channel. A field experiment was carried out in which, after a tritium release, water was sampled downstream from three locations along the channel at periodic intervals. Tritium was measured with a low-background liquid scintillation system and the concentration time evolution for each location was obtained. In order to obtain the channel longitudinal dispersion efficiency, the Unit Peak Attenuation (UPA) curve was plotted. The UPA slope curve was used to construct software that can estimate propagation time of soluble tracer cloud and unit peak attenuation at any location from studied area.

Introduction

River basins today are a foundation of economic production and ecological health, but are facing pressures from growing urban populations and agricultural and industry development. Nearly every major surface water body is at risk from pollution from a host of sources. Numerous experimental studies in hydrosphere have been carried out to study the hydrodynamic behavior of a wide type of stream. In most of these studies, chemical or fluorescent tracers are used, although they have various drawbacks, as they are usually nonperfectly conservative, their degradation products can be toxic and they are relatively expensive. The use of tritium as a tracer in river waters has several advantages [1]. It does not adsorb to sediments, being an ideal tracer as it forms water (HTO) molecules. Sampling is easy and it does not require special techniques. Small sample amounts can be used and extremely low tritium concentrations in water can be measured by low-background liquid scintillation. The relatively long life of tritium permits storage before measurement.

Materials and Methods

Danube-Black Sea Canal is ideal for tracers' study, because wastewater evacuations are occasionally due to technical operations of nuclear power plant. Tritiated water can be used to simulate the transport and dispersion of solutes in Danube-Black Sea Canal because they have the same physical characteristics as water, so understanding how tracers mix and disperse in a stream is essential to understanding their application in simulating pollution.

A conventional manner of illustrating the response in a stream to a tracer is to plot concentration variation with elapsed time [2]. The shape and magnitude of observed tracer-response curves are determined by four factors: the quantity of tracer injected, the degree to which the tracer is conservative, the magnitude of the stream discharge, and longitudinal dispersion. Observed concentrations can be adjusted for the amount of tracer, for tracer loss, and for channel discharge by use of so called “unit concentration”. Variations in dispersion on the same flow or different flows become most apparent if the unit concentrations for the peaks, C_{up}, are plotted as a function of elapsed time to the peaks. The UPA (Unit Peak Attenuation) curve, along with the travel time, provides a ready means of predicting, at any location, maximum contaminant levels that would be experienced downstream from any type of accidental spill. The final purpose of our study is to construct the UPA curve for Danube-Black Sea Canal.

The Danube- Black Sea Canal has the length of 64.410 km and is situated between the Port of Constanta South-Agigea “0” km of the canal and the junction with the Danube river-Cernavoda 64.410 km, respectively 299.300 km on the Danube river. The Danube-Black Sea Canal has two locks, one is located in Cernavoda and the other in Agigea and they are dividing the Canal in three sectors. The Danube-Black Sea Canal monthly water discharge attend a maximum in the summer months, around 23 m^3/s, and a minimum in winter months, around 6 m^3/s.The mean water velocity, assigned to the discharges, varies between 0.01 m/s and 0.047 m/s. There are no tributaries in the area, and the discharge is kept constant by the two existing locks. The Cernavoda NPP is situated in the beginning of the channel and comprises one heavy water reactor (HWR) unit. During its normal operation this unit generates low-activity radioactive waste, mainly tritium, which is released into Danube, in a controlled way, at Seimeni. Wastewater evacuations into the Canal are occasionally due to the technical operation of the nuclear power plant.

Two main locations were established before nuclear power plant: Cochirleni is situated on the Old Danube Branch, and Cernavoda before NPP. We used Cochirleni location to compare the tritium concentration of Cernavoda water samples, upstream of NPP. Some of the other locations offer easy access to sampling, by their channel pier: Faclia, Medgidia, Poarta Alba. In the chosen locations, water was sampled on the 5^{th} day of the month, during the period May 2002 – November 2002. Simultaneous sampling from centre and both sides of the channel in different location were considered, to compare the tritium concentration and to establish tritium concentration in cross section.

Special attention was given to samples collection and preservation [3]. As tritium is a soft beta emitter (5.72 keV mean energy), liquid scintillation is the most appropriate technique for its measurement. In this work, the low-background liquid scintillation spectrometer Quantulus 1220 (Wallac) has been used to determine tritium in channel water samples. The analytical method used to determine tritium in water samples was ISO method [4].

Results and Discussions

Applying the experimental formulas for the mixing length, we concluded that first location of the experiment could be Faclia, which is situated 10.6 km downstream of the junction of lateral Canal branch. The other two locations Medgidia (19 km downstream) and Poarta Alba (20.2 km downstream) helped to plot UPA curve, and to determine the slope, which is the efficiency of the Canal dispersion in this section. First step in obtaining basic information about studied area was to establish the baseline of tritium concentration.

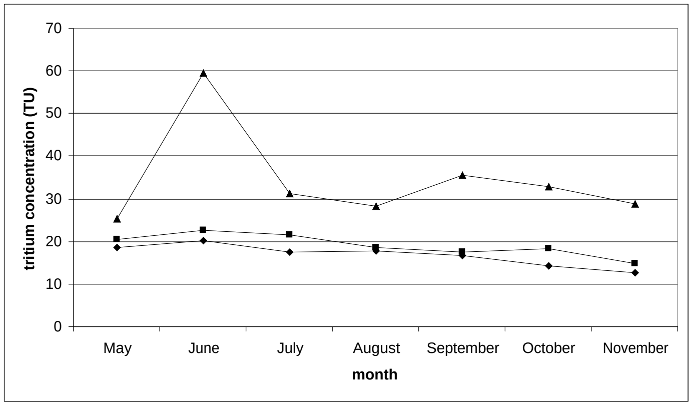

Fig. 1 Baseline of tritium level in studied aria (^ -Faclia, - - Cernavoda, -Cochirleni), monitoring period April 2002- April 2003.

During the monitoring period, May 2002- November 2002, there weren't wastewater releases from the Nuclear Power Plant, only the water necessary for basic technical operations. Cochirleni location was used to determine a mean tritium concentration in places without influences of NPP. A mean of 16.82 $\pm$ 2.7 TU for Cochirleni, against 19.02 $\pm$ 2.7 TU for Cernavoda town, fig.1, proves that upstream of NPP the influences of gaseous evacuation in water channel are minimum (1TU=1T atom to 10^{18} protium atoms). The tritium concentrations behaviour along the Channel is similarly like that of Faclia location, fig.1. There isn’t a seasonal variation, and a mean of 30 TU is the significant value for edge and tail of tracer cloud.

At the end of May 2003, it began the evacuation of tritiated water from NPP-Cernavoda in Danube-Black Sea Channel. We settled three observation locations: Faclia, Medgidia and Poarta Alba. The behavior of tritiated liquid effluents is similar to the tracer and it is illustrated in fig. 2. The water channel flow was around 30 m^3/s. We made simultaneous sampling on three streamlines (center and both side of the flow) in Medgidia location. The values confirm a behavior like a tracer at a distance greater than the mixing length, and relatively homogenous mixture of the tracer in the body water. From recorded values, the elapsed time for the edge of the tracer cloud was after 34 hours for Faclia location. The unit peak of concentration in this location was 62.72 s^{-1}. The elapsed time for the edge of the cloud in Medgidia location was 62 hours, with unit peak of concentration of 40.44 s^{-1}. The elapsed time for the edge of tritiated water in Poarta Alba location was 93 hours from the evacuation beginning, with a unit peak of concentration of 32.72 s^{-1}.

Drawing the UPA curve, we determined a mean of slope of 0.62 that indicate a lower efficiency of dispersion. Using experimental data obtained during this experiment we developed software that can evaluate the unit concentration in any location of observed area. In this way it can be predicted any maximum concentration of soluble pollutants that would be experienced downstream of a spill along the observed area of the Channel. All data obtained during this experiment offer a global evaluation of the flow along Danube-Black Sea Channel. It must be emphasized again that, the studied water has a very slow flow, the discharge is imposed by agricultural, human and dams consumption. In order to make a real evaluation of all the possibilities, it will be necessary to develop an experiment during the autumn-winter conditions.

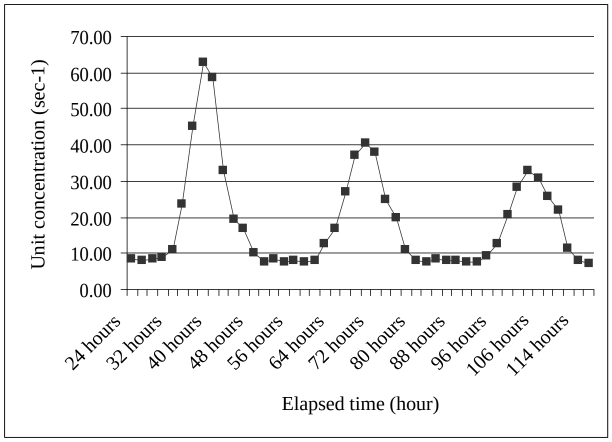

Fig. 2 The behavior of tritiated liquid effluents in three locations of Danube – Black Sea Channel

Conclusions

The theory of the soluble tracers can be applied in the case of tritiated wastewater of NPP Cernavoda, for Danube-Black Sea Canal. In order to plan the sampling campaign we established the proper mixing length for the Canal flow, and the locations with easy access for tracer experiments. In these locations we established significant tritium concentrations for the edge and the tail of tritiated wastewater evacuations. During the evacuations of tritiated liquid effluents we determined the slope of the UPA curve, that help us to model the water movement in observed area of Danube-Black Sea Channel. We can predict, in this way, maximum concentration of soluble pollutant accidental spills in studied area, using specific software developed in this work.

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