DESCRIPTION

MICROORGANISM EVALUATION SYSTEM

RELATED APPLICATIONS:

[0001] This application claims priority to and is entitled to the filing date of U.S. Provisional application Ser. No. 61/661,011 filed June 18, 2012, and entitled "Microorganism Evaluation System." The contents of the aforementioned application are incorporated herein by reference.

INCORPORATION BY REFERENCE:

[0002] Applicant(s) hereby incorporate herein by reference any and all patents and published patent applications cited or referred to in this application.

TECHNICAL FIELD:

[0003] Aspects of this invention relate generally to testing systems, and more particularly to evaluation systems for determining whether microorganisms are living.

BACKGROUND ART:

[0004] By way of background, a number of industries are affected by regulations relating to water treatment, such as ballast water treatment systems ("BWTS") on ships and the like. Such regulations require that microorganisms be effectively treated (killed) by the BWTS before such water is returned to the ocean or other body of water. Generally speaking, Zooplankton in the size range of approximately 10 to 50 microns is an "indicator" microorganism used to determine the effectiveness of treatment. To date, monitoring of the effectiveness of such BWTS has largely been handled through samples submitted to a lab, there most often involving human examination under a microscope. Such approaches to compliance assessment have numerous

shortcomings in terms of accuracy, speed, and cost. Similarly, flow cytometry systems, though offering relatively higher throughput, are also lacking in terms of viability determination (determinations regarding whether an organism is living) and portability for field or deployed uses.

[0005] The following art defines the present state of this field:

[0006] International Pub. No. JP WO2005106454S dated March 21, 2008 is directed to subject matter teaching that to be viable in the antigen by specifically labeled, as among a viable microorganisms can be detected rapidly in a short time, the reliability of inspection and detection method can also be guaranteed. Such as an antigen, Escherichia coli, viable to be examined in the antigen (target bacteria 12) enzymatic decomposition by the sign material 13 is brought into action after generating a labeled antigen 14, specifically to subject the specific coupling in a stationary phase is formed by fixing an antibody, an antigen labeled 14 thereof to and captured.

[0007] U.S. Patent Application Pub. No. US 2009/0162887 to Kaduchak et al. dated June 25, 2009, is directed to a method and apparatus for acoustically manipulating one or more particles.

[0008] U.S. Patent Application Pub. No. US 2010/0041122 to Ragsdale dated February 18, 2010, is directed to membrane-encased structures such as biological cells, liposomes, and vesicles, conveyed through one or more channels in a rotating disk for individual exposure to optical elements or to electrodes, for purposes of transfection or flow cytometry. The rotation of the disk serves either to provide centrifugal force to urge the cells against one wall of the channel and in certain embodiments to move the cells through the channels, or to draw cells at preselected times or intervals into the exposure zone, or all three.

[0009] U.S. Patent Application Pub. No. US 2010/0116647 to Kornmuller et al. dated May 13, 2010, is directed to a water treatment plant, in particular ballast water treatment plant, for

removing sediments and/or removing and/or destroying living organisms, which has at least one filter unit (B) and at least one disinfection unit (C), wherein the plant has a detection unit (D) by means of which the number of living organisms of a presettable size per unit volume of water can be determined, and in that the plant has a control unit, by means of which the disinfection unit (C) can be controlled as a function of the number of living organisms which has been determined.

[0010] U.S. Patent Application Pub. No. US 2010/0157291 to Kiesel et al. dated June 24, 2010, is directed to a method wherein sensors can be used to obtain encoded sensing results from objects that have nonuniform relative motion. A photosensor or impedance-based sensor, for example, can obtain sensing results from objects that have relative motion within a sensing region relative to the sensor, with the relative motion being, for example, periodically varying, randomly varying, chirp-varying, or modulated relative motion that completes at least one modulation cycle within the sensing region. Relative motion can be caused by varying objects' speed and/or direction or by controlling flow of fluid carrying objects, movement of a channel, movement of a support structure, movement of a sensor, and/or pattern movement. A fluidic implementation can include shaped channel wall parts and/or a displacement component causing time-varying lateral displacement. A support structure implementation can include a scanner device and a rotary device that respectively control scanning and rotating movement of a movable support structure or of a sensor.

[0011] Japanese Patent Application Pub. No. JP 2012020218 dated February 2, 2012, is directed to a system wherein the liquid supplied to the ballast tank 103 in the sterilization of microorganisms hydrophyte for sterilization device 101 and 1, ballast water in the ballast tank 103 for sterilization device 102 and the second, first the liquid 1 sterilization treatment device 101 for supplying the chest 104 of the ballast from the ballast tank 103, 105 and connected to a water supply line, 2 sterilization treatment device 102 includes a first liquid containing sodium chloride, sodium hypochlorite by electrolysis in the electrolytic cell for generating the ballast water treatment system is provided.

[0012] U.S. Patent No. 8,153,950 to Kiesel et al. dated April 10, 2012, is directed to an encoder/sensor can obtain sensing results from objects in an encoding/sensing region; a trigger detector can respond to objects in a trigger detection region, providing respective trigger signals; and a relative motion component can cause relative motion of objects into the trigger detection region, from it into the encoding/sensing region, and within the encoding/sensing region. In response to an object's trigger signal, control circuitry can cause the encoder/sensor and/or the relative motion component to operate so that the encoder/sensor obtains sensing results indicating a time-varying waveform and processing circuitry can obtain data from the sensing results indicating a time-varying waveform. The time-varying waveform can include information resulting from the relative motion within the encoding/sensing region. The encoder/sensor and trigger detector can be implemented, for example, with discrete components or as sets of cells in a photosensing array on an integrated circuit.

[0013] U.S. Patent Application Pub. No. US 2012/0115723 to Stimson et al. dated May 10, 2012, is directed to a composition for treating waters, e.g. ballast water or injection water for oil recovery, to kill in-situ aquatic invasive species comprises at least one biocide capable of killing both animal and plant micro-organisms. The at least one biocide preferably comprises Brilliant Green, Gentian Violet, and/or erythrosine, and a wetting agent or detergent-like compound such as CTAB or CTAC. The invention also relates to a system for treating ballast water in situ comprising means for injecting a composition for treating ballast water; means for measuring the flow rate or amount of ballast water to be treated; means for controlling the dosing of the composition; and means for storing or receiving the composition. The invention also relates to a method of detecting viable aquatic organisms in ballast water in situ comprising detecting metabolism in viable micro-organisms in ballast water and, therefore, measuring the efficacy of any treatment.

[0014] The prior art described above teaches a viable specifically labeled antigen detection and detection device for detecting method, a particle analysis in an acoustic cytometer, a centrifugal

force-based system for detection/treatment of membrane-encased structures, a ballast water treatment plant having filter, disinfection, instrumentation and control unit, a system for causing relative motion, a ballast water treatment system and ballast water treatment method, a system and method for obtaining sensing results and/or data in response to object detection, and a ballast water treatment system, but does not teach a means for imparting at least inertial stimulation to organisms within a fluid flow for the purpose of determining whether organisms are living based on detected responsive movement and/or motion of the organisms. Aspects of the present invention fulfill these needs and provide further related advantages as described in the following disclosure.

DISCLOSURE OF INVENTION:

[0015] Aspects of the present invention teach certain benefits in construction and use which give rise to the exemplary advantages described below.

[0016] The present invention solves the problems described above by providing an evaluation system for determining whether a microorganism is living. The system provides, in the exemplary embodiment, a microorganism evaluation system for analyzing microorganisms within a fluid flow, comprising a microorganism stimulation section comprising a means for inducing a motive response in a living microorganism capable of such within the fluid flow passing through the microorganism stimulation section, and a viewing section in fluid communication with the microorganism stimulation section, the viewing section comprising a body having formed therein a body cavity defining a viewing port visible through a cavity first opening formed in the body so as to be in communication with the body cavity, the viewing section further comprising an optical system mounted relative to the body for viewing the fluid flow within the viewing port through the cavity first opening, whereby image data relating to the fluid flow and microorganisms therein is acquired via the optical system for analysis.

[0017] A primary objective inherent in the above described system and method of use is to provide advantages not taught by the prior art.

[0018] Another objective is to provide such a system wherein a flow normalizing section is in fluid communication between the microorganism stimulation section and the viewing section, the flow normalizing section comprising an inlet chute having a tapered inlet chute inner bore.

[0019] Yet another objective is to provide such a system wherein a sample pre-conditioning section is upstream of and in fluid communication with the microorganism stimulation section.

[0020] Other features and advantages of aspects of the present invention will become apparent from the following more detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of aspects of the invention.

BRIEF DESCRIPTION OF DRAWINGS:

[0021] The accompanying drawings illustrate aspects of the present invention. In such drawings:

[0022] Figure 1 is a block diagram illustrating an exemplary microorganism evaluation system, in accordance with at least one embodiment;

[0023] Figure 2 is a schematic representation thereof, in accordance with at least one embodiment;

[0024] Figure 3 is an enlarged partial schematic representation thereof taken along line 3-3 of Fig. 2, in accordance with at least one embodiment;

[0025] Figure 4 is an enlarged partial schematic representation thereof taken along line 4-4 of Fig. 3, in accordance with at least one embodiment;

[0026] Figure 5 is a partial perspective view thereof, in accordance with at least one embodiment;

[0027] Figure 6 is an exploded perspective view thereof, in accordance with at least one embodiment;

[0028] Figure 7 is an exploded perspective view thereof taken from substantially the opposite direction as Figs. 5 and 6, in accordance with at least one embodiment;

[0029] Figure 8 is an enlarged partial perspective view thereof, in accordance with at least one embodiment;

[0030] Figure 9 is an enlarged partial top cross-sectional view thereof taken along line 9-9 of Fig. 6, in accordance with at least one embodiment;

[0031] Figure 10 is an enlarged partial side cross-sectional view thereof taken along line 10-10 of Fig. 6, in accordance with at least one embodiment;

[0032] Figure 11 is an enlarged partial top cross-sectional view thereof taken along line 11-11 of Fig. 6, in accordance with at least one embodiment;

[0033] Figure 12 is an enlarged partial side cross-sectional view thereof taken along line 12-12 of Fig. 6, in accordance with at least one embodiment;

[0034] Figure 13 is an enlarged partial bottom view thereof, in accordance with at least one embodiment;

[0035] Figure 14 is an enlarged partial cross-sectional view thereof taken along line 14-14 of Fig. 5, in accordance with at least one embodiment;

[0036] Figure 15 is a flow chart representing the use thereof, in accordance with at least one embodiment;

[0037] Figure 16A is a schematic representation of a self-induced change in the direction of movement of a microorganism;

[0038] Figure 16B is a schematic representation of a self-induced change in the orientation of a microorganism;

[0039] Figure 16C is a schematic representation of a self-induced change in the aspect ratio of a microorganism;

[0040] Figure 17A is a graph depicting the inertial stimulation over time to which the microorganism is subjected, in accordance with at least one embodiment;

[0041] Figure 17B is a graph depicting the response of a microorganism over time in response to the inertial stimulation depicted graphically in Fig. 17A, in accordance with at least one embodiment;

[0042] Figure 18 is a partial schematic representation of an alternative exemplary microorganism evaluation system, in accordance with at least one embodiment;

[0043] Figure 19 is a partial schematic representation of a further alternative exemplary microorganism evaluation system, in accordance with at least one embodiment; and

[0044] Figure 20 is a partial schematic representation of a still further alternative exemplary microorganism evaluation system, in accordance with at least one embodiment.

[0045] The above described drawing figures illustrate aspects of the invention in at least one of its exemplary embodiments, which are further defined in detail in the following description. Features, elements, and aspects of the invention that are referenced by the same numerals in different figures represent the same, equivalent, or similar features, elements, or aspects, in accordance with one or more embodiments.

MODES FOR CARRYING OUT THE INVENTION:

[0046] The above described drawing figures illustrate aspects of the invention in at least one of its exemplary embodiments, which are further defined in detail in the following description.

[0047] In general, according to aspects of the present invention, batch or continuous real time monitoring is deployable within ballast water treatment systems and the like and provides further advantages over prior art test systems and approaches, the support of continuous real time monitoring being particularly advantageous for several applications. The subject invention, though again in the context of BWTS compliance testing, may be practiced in a wide array of contexts and so is not limited to the exemplary BWTS context (for example, monitoring invasive species migration in fresh and salt water bodies, bioterrorism, etc.). Thus, while "water" is discussed throughout as the sampled fluid, it is to be understood that the invention is not so limited and other fluids may be sampled as well, again depending on the context.

[0048] As an overview, and with reference to Figure 1, the exemplary microorganism evaluation system **20** has four main hardware components or sections, which are discussed in turn below: (1) a sample pre-conditioning section **30**; (2) a microorganism stimulation section **80**; (3) a flow normalizing section **100**; and (4) a viewing section **120**. There are related tanks, tubes, flow controls and other aspects that facilitate the collection and processing of the water sample, which may be necessary in particular contexts but are nevertheless ancillary components

that can be substituted for by other equivalent structure (e.g. pumps, etc.), and so are not the focus of the present invention. It will be appreciated by those skilled in the art that the exact configuration of the system and its four main sections may take a number of forms to suit particular applications without departing from the spirit and scope of the present invention. Accordingly, it will be further appreciated that the configurations of the system shown and described are exemplary and that the invention is not so limited. Moreover, once again, while "water" is discussed throughout as the sampled fluid, it is to be understood that the invention is not so limited and other fluids may be sampled as well, again depending on the context. Relatedly, it is assumed for these purposes that whatever fluid is sampled it contains microorganisms, some living and some dead, such as Zooplankton in the size range of approximately 10 to 50 microns, for example. It is further noted as a threshold matter that the present focus of the subject invention is in determining whether certain microorganisms are living, as again evidenced by a motive response of some kind, and not necessarily whether such an organism is "viable" in the sense that it is capable of living for an extended period, reproducing, etc., it being understood that all viable organisms are living but that not necessarily all living organisms are viable, though it will be appreciated that inherently the present invention will identify viable organisms as it does living ones.

[0049] With continued reference to Fig. 1, the block diagram shows the exemplary embodiment of the microorganism evaluation system **20** according to aspects of the present invention as generally comprising a sample pre-conditioning section **30** configured in fluid communication with a sample source **S** so as to receive and process a fluid sample and pass such sample along to a microorganism stimulation section **80** configured to agitate, excite, or otherwise stimulate one or more senses of any living microorganisms in the fluid sample. The sample pre-conditioning section **30** is shown as comprising an external sample tank **32** that receives the fluid flow from the sample source **S** and then passes such fluid on to a main sample tank **52** before then flowing to the microorganism stimulation section **80**, though it will be appreciated that a variety of means for acquiring and passing along a fluid sample, static or dynamic and now known or later developed, may be employed without departing from the spirit

and scope of the present invention, such that the two tanks in series are to be understood as merely exemplary of aspects of the invention. A flow normalizing section **100** is downstream of and in fluid communication with the microorganism stimulation section **80** for the purpose of slowing and/or rendering more laminar the fluid flow after it leaves the stimulation section **80**, which may involve agitation of not just the organisms but the fluid itself. Downstream of and in fluid communication with the flow normalizing section **100** is a viewing section **120** configured for passing the flow therethrough and obtaining image data thereof. More particularly, in the exemplary embodiment, the viewing section **120** comprises an illuminator **150** for providing lighting to the viewing section **120**, an optical system **160** for actually acquiring image data as would a camera or camera-like device, and an imager **170** for processing or manipulating the image data from the optical system **160**. It will be appreciated that throughout when a "camera" is discussed is being the "optical system **160**" or equipment that any such device, whether "off the shelf" or proprietary, may further include imaging capability, that is, the ability to capture and manipulate image data with sufficient frame rate and resolution, such that in fact the "optical system **160** and the imager **170** may be a single device in the form of a "camera" or the like. From the viewing section **120** the fluid flow proceeds to a sample return **R**. Further regarding the microorganism evaluation system **20**, and the viewing section **120** specifically, there is shown a separate image capture and processing device **210** (hardware and software) in communication with the viewing section **120**, which device **210** is configured for taking the image data from the imager **170** and further processing the data for analysis. The image capture and processing device **210** may be any computer or processor or computing or processing device now known or later developed and may be wired or wirelessly connected to the viewing section **120**, or may be incorporated into the viewing section **120**, and the imager **170** specifically, again for the purpose of acquiring and processing the image data obtained by the optical system **160**. Moreover, the entire viewing section **120** may be a proprietary and/or unitary device or may be comprised of one or more "off the shelf" components operably connected and configured according to aspects of the present invention, such as, for example, employing a digital camera as the optical system **160** and outputting image data from such camera using its high-speed interface such as USB 2, HDMI, or other appropriate interface to a computer configured to

operate as the imager **170** and image capture and processing device **210**, or the viewing section **120** may be some combination thereof. Such computer may further have installed and run the kinematics analysis algorithm **212**, or such algorithm **212** may be configured to operate on a separate computer or computing device. Ultimately, those skilled in the art will appreciate that the components of the viewing section **120**, namely, the illuminator **150**, the optical system **160**, and the imager **170**, and the related image capture and processing device **210** and kinematics analysis algorithm **212** may be configured in a variety of ways in one more devices without departing from the spirit and scope of the present invention, such that it is to be understood that the particular arrangement shown in Fig. 1 and elsewhere herein is merely illustrative of features and aspects of the present invention and non-limiting. Specifically, it will be appreciated that the image capture and processing device **210** and kinematics analysis algorithm **212** may be physically configured within the microorganism evaluation system **20** or not but are nevertheless components of the overall system **20** as represented by the block diagram of Fig. 1. Furthermore, any of the components of the system **20** may or may not be integral or packaged in a unitary way without departing from the spirit and scope of the invention.

[0050] Turning now to Figure 2, there is shown a schematic view, not to scale, of an exemplary embodiment of the microorganism evaluation system **20** according to aspects of the present invention as shown in the block diagram of Fig. 1. Going in sequence as a water sample would be processed through the system **20**, and thus starting upstream of the stimulation section **80**, there is again first the sample pre-conditioning section **30**. This pre-conditioning section **30** can be implemented in different ways. For example, in real time continuous sampling applications the pre-conditioning function can be accomplished by utilizing the differing inertial characteristics of the particulates contained in the sampled fluid. Or, isokinetic or other techniques for sampling from a continuous flow now known or later developed may be substituted for the one or more tanks **32**, **52** of the exemplary embodiment without departing from the spirit and scope of the present invention. Back to the discrete or static sample application, a removable external sample tank **32** is provided as a container into which a test sample is to be initially collected. While in Fig. 2 the initial external sample tank **32** is shown as

being physically outside of the system, it is nevertheless part of the system **20**, or the sample pre-conditioning section **30** specifically, as once again shown in the block diagram of Fig. 1. Such an external sample tank **32** may comprise a cap and vent **36** removably positioned in an inlet **34** and an external sample tank buoyant intake **40** configured with a filtered opening and a turbidity detection device (not shown) through which the sample fluid passes on its way to an outlet **38** of the external sample tank **32**. By employing a buoyant sample intake **40**, the intake is configured to resist dropping low enough in the tank **32** to pull in mud and other particulates that have settled to the bottom of the tank **32**. The external sample tank **32** is thus configured as an initial sample fluid holding tank in which the sample is effectively pre-conditioned, particularly as to turbidity, before passing onto other portions of the microorganism evaluation system **20**. Thus, the external sample tank **32** being removable facilitates the disposal of unwanted particulates such as mud deposits from turbid water and other inorganic or "dead" materials. A tank tubing **42** connects the outlet **38** of the external sample tank **32** to an inlet **54** of a main sample tank **52** installed within the system **20**, the tubing **42** passing through a first opening **24** in the box or case or other such enclosure **22** in which the overall microorganism evaluation system **20** is installed and being coupled to the main sample tank **52** through a quick disconnect coupling **44** and a flow control **46** that cooperates with other aspects of the system's control sub-system in moving the fluid therethrough. Within the main sample tank **52**, a down tube in the exemplary embodiment defining the inlet **54** is in fluid communication with the tubing **42** so as to effectively deliver the fluid from the external sample tank **32** to the bottom portion of the main sample tank **52**, again for reasons related to turbidity and, more generally, consistent sample density during the sampling event. As with the external sample tank **32**, the main sample tank **52** is also configured with a vent **56** and with a main sample tank buoyant intake **62** configured with a filtered opening through which the sample fluid passes on its way to an upper main sample tank first outlet **58**. The main sample tank **52** is further configured with a lower main sample tank second outlet **60** having a main sample tank filtered intake **64** to allow fluid to pass therethrough as a means of essentially regulating the out-flow, in cooperation with the proportional flow valve **70** discussed below, such that the higher the column height of fluid in the main sample tank **52**, the greater the tendency of fluid to pass out of the lower outlet **60**, and

vice versa. In other words, during the earlier period of the sampling event when the sample is at the greatest level in the tank **52**, relatively less sample will flow from the buoyant intake **62** and relatively more from the lower fixed intake **64**, and during the later period of the sampling event when the sample is at the lowest level in the tank **52**, relatively more sample will flow through the buoyant intake **62** and relatively less sample will flow through the lower fixed intake **64**. Moreover, since it is known that indicator organisms such as Zooplankton within a water sample will generally be at relatively greater concentrations at or near the surface and relatively lower concentrations at or near the bottom of a body of water, by employing two outlets – one that floats and rises and falls with the water level in the tank and one that is fixed at the bottom or substantially lowest point of the tank – once more the objective of providing greater consistency in the density of the Zooplankton or other organism within the sample is achieved. Furthermore, an upper outlet tubing **66** in fluid communication with the upper outlet **58** and a lower outlet tubing **68** in fluid communication with the lower outlet **60** both are in fluid communication with a proportional flow valve **70** that further cooperates with the upper and lower outlets **58**, **60** to regulate and normalize the flow of fluid from the main sample tank **52**, the proportional flow valve **70** also mixing the fluid from the twin intakes **62**, **64**, again in the interest of yielding a relatively consistent sample density during the sampling event from the main sample tank **52**. Downstream of the pre-conditioning section **30** there is operably positioned a second flow control **74** in fluid communication with the proportional flow valve **70** view tubing **72** that once again cooperates with other aspects of the system's control sub-system in moving the fluid therethrough and on to the microorganism stimulation section **80** and the rest of the microorganism evaluation system **20**, as described further below. The flow control sub-system or any other devices such as pumps would effectively operate on a continuity principle aimed at providing a relatively clean, smooth, and consistent flow of fluid being sampled. Those skilled in the art will again appreciate that while an exemplary multiple-sample tank set-up is shown and described in connection with the exemplary microorganism evaluation system **20**, each tank having respective inlets, outlets, vents, filters, and buoyant sample intakes and the fluid moved therethrough in cooperation with or under the control of one or more flow controls, the invention is not so limited, for example, as indicated, such sampling may instead involve a

continuous real time monitoring scheme. Thus, any such sample collection, holding, and delivery hardware and related controls now known or later developed may be practiced in conjunction with the present invention without departing from its spirit and scope, such that the disclosed tank set-up is to be expressly understood as illustrative and non-limiting. More generally, the disclosed tank sub-system or other equivalent structure facilitates improved system performance through: (i) separation of live organisms from dead or inorganic material; (ii) removal of a significant amount of non-live material within the external sample tank **32** before entering the main sample tank **52** and rest of the microorganism evaluation system **20**; (iii) lowering maintenance requirements due to reduced inorganic ingestion; (iv) mitigating the consequence of a relatively turbid water sample; and/or (v) providing a relatively less cluttered sample due again to the sample's relatively fewer dead or inorganic matter.

[0051] Regarding the microorganism stimulation section **80** within the microorganism evaluation system **20** that follows the tank sub-system or pre-conditioning section **30** above-described, and as further background, the general idea is that the microorganisms in the water being sampled/tested will physically respond to stimuli if they are alive and not if they are dead. This is, in fact, how it is done in the lab under a microscope, with the technician "poking" the organisms to see if movement can be observed. It is thus important to provide adequate stimulation of the microorganisms in a way that will cause a clearly detectable reaction by a living microbe; a microorganism that is alive will respond to the stimulation from this section **80** by generating its own movement, which self-generated movement is then isolated from the movement of the fluid sample in the flow normalizing section **100** and then detected in the viewing section **120**, more about which is said below. It will also thus be further appreciated that the pre-sampling removal of dead or inorganic matter through settling or otherwise within the pre-conditioning section **30** again thereby contributes to the effectiveness of the downstream system, where the focus is to be on stimulating and detecting live microorganisms capable of motive response. But those skilled in the art will also appreciate that in some contexts the sample pre-conditioning section **30** will simply not be required, such as situations wherein the water sample has low turbidity or wherein the means of acquiring the sample, which of itself

could be seen as another type of sample pre-conditioning device, is adequate to allow for meaningful downstream evaluation of organisms within the sample.

[0052] With continued reference to Fig. 2, then, in the first exemplary embodiment, an inertial disorientation section ("agitator") or microorganism stimulation section **80** is provided downstream of the sample pre-conditioning section **30** in order to subject the microorganisms to motive stimulation (agitator # 1). Here, the stimulation section **80** is configured as a helix tube or disorientation spiral **82** having most likely more than one loop, though it will be appreciated that additional loops of various sizes and configurations can be added as required, any such geometries being dictated, at least in part, by the input determined for proper inertial stimulation of the microorganism. The theory is that the helix geometry of the disorientation spiral **82** will induce the fluid in the tube to rotate around the tubular axis, which will stimulate (agitate) the inertial sensing mechanisms found within the microorganisms, more about which is said below in connection with Figs. 15 and 16.

[0053] Still in connection with Fig. 2, after the sample water leaves the microorganism stimulation section **80** wherein the flow is twisted and inertial effects are induced, it is then desirable to provide a flow normalizing section **100**, or a section of the system conduit wherein the sample fluid has sufficient distance over which it is able to become relatively laminar, or wherein the radial or spiral flow is dampened out on its way to the viewing section **120**. However, it will be appreciated that such dampening or relatively laminar flow may be achieved simply in the exit from the disorientation spiral **82** depending on its length and the diameter and surface features (smoothness or roughness) of the spiral bore **92** (Fig. 8) and/or in the viewing section body inlet **124** or viewing port **144** itself (Figs. 3 and 4), such that in some embodiments the flow normalizing section **100** may not be employed. It will also be appreciated that such a normalizing section **100** may not be required at all or to the same extent in embodiments of the system wherein PSD direct or indirect hydraulic stimulation is employed, for example, such as in the alternative embodiments of Figs. 17 and 18. Again, the primary purpose of the flow normalizing section **100** when it is employed is to effectively isolate self-generated movement of

a microorganism from the movement of the fluid sample. In this way, once the fluid flow is returned to substantially "straight-line," any continued movement of a microorganism, as detected in the viewing section **120**, would be deemed self-generated motion, as opposed to flow-generated motion. Thus, the normalizing inlet chute **102** (Figs. 3, 5-7, 9 and 10) between the stimulation section **80** and the viewing section **120** of the microorganism evaluation system **20** is shown as being a relatively long, substantially linear chute that supports normalizing microorganism motion by providing a travel time that is less than the "disorientation response decay time" of the microorganisms, or the time from the reaction to the stimulation event beyond which an organism's induced response would be expected to cease, which for Zooplankton and other such organisms is thought to be on the order of 5-10 seconds. In other words, the normalizing chute **102** as in the exemplary embodiment is to be long enough to allow the flow to "straighten out" while not being so long that at the system's characteristic flow rate the disorientation response decay time for the microorganisms is exceeded by the time the fluid sample reaches the viewing section **120** from the stimulation section **80**, such that self-generated movement of some kind would potentially not be seen in the viewing section **120** even for living or viable organisms. This "sizing" of the flow normalization section **100** and the inlet chute **102** particularly may be accomplished by utilization of CFD ("computational fluid dynamics") analysis to determine the length of the chute **102** required to normalize the motion of the microorganism before the viewing section **120**, with one such exemplary inlet chute **102** geometry being shown and described below in connection with Figs. 5-7, 9 and 10, though it will be appreciated by those skilled in the art that a number of other geometric variations and methods of their determination are possible depending on a variety of factors, again including the microorganism type and the fluid type. It will be additionally appreciated, as discussed further below, that the length of the normalizing chute **102**, in the case of a substantially vertical arrangement of the flow normalizing section **100** as depicted schematically in Fig. 2, is the leading contributor to the overall column height of water within the system **20**, or the change in height within the system **20** from the water level within the main sample tank **52** to the overall system exit or discharge point of sample return tube **200**, which column height will not only

have an influence on system flow rate but also create a pressure variance to which the microorganisms can respond as well.

[0054] Turning next to the viewing section **120** shown schematically in Fig. 2, the fourth major hardware component or section of the microorganism evaluation system **20** according to aspects of the present invention, there are a number of features involving the physical, geometrical set-up alone that are specifically designed to accomplish the necessary data acquisition and are addressed in turn herein. The basic idea is that once the fluid sample has been pre-conditioned in the sample pre-conditioning section **30**, the microorganisms within the sample have been stimulated in the stimulation section **80**, and the flow within the system **20** regulated in the flow normalizing section **100**, in the viewing section **120** visual data on the microorganisms is then obtained to support kinematics analysis and thereby determine whether any of the organisms are alive. First, as the flow enters the inlet chute **102** as schematically represented in Figure 3, it basically flattens out and slows down through an expansion which causes a deceleration (negative acceleration or "-a"). The profile or cross-sectional area of the deceleration chute **102** is such to transition from the circular cross-section of the disorientation spiral **82** of the microorganism stimulation section **80** to a relatively larger rectangular cross-section of the viewing section **120**, more about which is said below. The deceleration chute thus serves to reduce and normalize microorganism velocity through velocity change while not corrupting the self-induced relative motion of any organisms that are living. In fact, such deceleration or change in flow velocity is effectively another stimulus (agitator # 2) to a living microorganism's sensory perception that would tend to induce further self-movement just before the organism enters the viewing section **120**, even while the flow itself is slowing and further normalizing. Those skilled in the art will appreciate that such normalization is also desired, in part, in order to account for the relative difference in velocity across the profile as caused by the pipe walls, the flow and thus microorganism velocity at the center of any pipe being greater than at the walls where shear forces act on the fluid. The desirability of the flow or organism velocity slowing and normalizing prior to entering the actual viewing section **120** will be further appreciated upon consideration of the operation of the viewing section **120** itself.

[0055] In general, and with reference to Figs. 2 and 3 and now Figure 4, the viewing section **120** comprises a substantially flat or rectangular profile flow path through which optical equipment such as a digital camera "looks." It is contemplated that twenty (20) or more frames for each organism are desirable as a data set in order to draw conclusions about the organism's relative movement. It will thus be appreciated that obtaining the desired number of frames is essentially a function of the flow rate through the viewing section **120** and the optical equipment's imaging capabilities (optical system **160** and imager **170**). Put another way, there are two primary aspects regarding the viewing section **120**: (i) depth of field; and (ii) transit time – that is, through what cross-section can the optical equipment focus at a time, and how long is the segment of interest of the fluid within the viewer in order to get the snapshots for the data set. Accordingly, regarding the depth of field, the viewing section **120** preferably flattens out into a substantially rectangular profile defining the viewing port **144** of the viewing section **120** that is somewhat commensurate with the view angle or field of view of the optical system **160** (the camera or other optical sensor/equipment being used) and that has a depth that is within the focal length range of the optical system **160**. Assuming currently available imaging components (lens field of view and focal lengths, resolution (on the order of twenty-four (24) megapixels), and full pixel array frame-rate), the aspects of the system of the present invention that dictate the function and performance of the viewing section **120** are primarily geometrical. For example, a camera capable of shooting at least ten (10) frames per second ("fps") at a processed "resolution" or image quality of at least 2 megapixels ("mp"), or a processed "1080P high definition video" as presently known, would be adequate for purposes of the present invention. Clearly, as technology advances are made, even faster or higher resolution digital cameras may be employed, which may then allow for higher sampling or flow rates and/or a smaller viewing section **120**. More particularly, any such digital camera employed in the present invention may be characterized by a CCD (charge-coupled device)- and/or CMOS (complementary metal-oxide semiconductor)-based sensor or imager, though again it will be appreciated that any such digital imaging technology now known or later developed may be employed according to aspects of the present invention. Irrespective of the digital imaging technology employed, maintenance of

relatively laminar or normalized flow and a proper microorganism velocity profile through the viewing section **120** so as to not compromise the data collected (relative movement detected is due to microorganism self-generation, not flow turbulence) is a related and overarching consideration of the present invention. Further regarding the viewing section **120**, also integral to the assembly as shown in Figs. 2-4 is an LED-based illuminator **150** or light source substantially adjacent to the viewing section **120**, possibly opposite the optical system **150** as shown in Fig. 2. Or, as shown in Fig. 4, the illuminator **150** may comprise a background illuminator **152** opposite the optical system **160** and one or more front illuminators **154** adjacent the optical system **150**, with further variations on the illuminator **150** shown and described in connection with Fig. 5 and following, further below. Not only does the illuminator **150** facilitate image acquisition by the imager **170** of the microorganisms within the fluid sample, but it will be appreciated that this "step change" in light provides yet another stimulus to the organisms themselves within the viewing section **120** itself (agitator # 3), it being known in the art that such organisms often have photoreceptors or other capability of detecting and responding to light. Finally, to complete the viewing section **120**, in the exemplary embodiment, the flow therethrough exits by way of a contraction or funnel of sorts, shown and described as an acceleration ("+a") chute or outlet chute **182**. Much like the deceleration chute **102** at the inlet to the viewing section **120**, the acceleration chute **182** profile or cross-sectional area is such to transition from the rectangular cross-section of the viewing section **120** to the relatively smaller circular cross-section of now the exit tubing **196**. Downstream of the viewing section and the exit tubing **196** there is positioned effectively a third flow control **198** (flow control **46** and pressure/flow control **74** being upstream), which again cooperates with other aspects of the system's control sub-system in moving the fluid therethrough. Moreover, as mentioned above, there is effectively a column height of water within the system **20**, or a difference in height within the system **20** from the water level within the main sample tank **52** to the overall system exit or discharge point effectively at the point of the third flow control **198**, which column height creates a pressure variance that is yet another stimulus to which the microorganisms can respond (agitator # 4). In more detail, Zooplankton in particular tends to generate vertical motion to adjust its depth, which is why higher concentrations of such organisms are typically

found at or near the surface of a fluid versus deeper within the fluid. Therefore, such pressure differential or variance as is a natural byproduct of the physical set-up and spatial orientation of the exemplary microorganism evaluation system **20** as shown and described herein, which again serves as another stimulus or means of exciting self-generated motion in the microorganisms. It will thus be appreciated that as the fluid flows downwardly through the system, and particularly the inlet chute **102** of the flow normalizing section **100** on its way to the viewing section **120**, living organisms will have a tendency to attempt to "swim upstream" seeking areas of relatively lower pressure. It would be an object of the system **20** to then detect any and all such motion by living microorganisms passing through the viewing section **120** so as to thereby evaluate or document organism effective viability within the test sample. Accordingly, and to further facilitate the control and use of such a pressure differential within the system, in the exemplary embodiment, the third flow control **198** is also configured with a pressure change or "ΔP" control that can be used to manipulate pressure within the system **20**, and indirectly flow rate. Once more, those skilled in the art will appreciate that such structure and functionality may be substituted for by other technology now known or later developed without departing from the spirit and scope of the invention. For example, while a substantially vertical arrangement of the system **20** is shown and described in connection with the exemplary schematic of Fig. 2, it will be appreciated that such a spatial orientation or relationship among the components is merely illustrative. More particularly, while a "column height of water" has been discussed as one means of employing a change in pressure as another "agitator" or stimulation to an organism's senses within a fluid sample flowing through the system **20**, it will be appreciated that pressure differential can be created in a variety of other ways employing pumps, valves, restrictions, and the like, or in some contexts such a "ΔP" agitator may be nominal if employed at all. In the exemplary embodiment, then, a pre-viewing section region, or deceleration or inlet chute **102**, is configured as an expansion within the flow path to decelerate or slow the flow and hence the microorganisms to the desired viewing speed before reaching the primary viewing section **120** adjacent the imaging system. The portion of the viewing section **120** immediately beneath the optical system **160** (camera) is then effectively flattened such that from the side it may even be thinner than the conduit while from above it is relatively wider. The result again in the

exemplary embodiment is a cross-sectional area within the viewing section **120** that is greater than that of the flow conduit, again contributing to a slower, relatively laminar flow and "normalized" motion of the organisms as they flow through this area, while also providing a thinner vertical section or "depth of field" for the viewing section **120**, enabling the imaging system (optical system **160** and imager **170**) to acquire visual data on the microorganisms at any depth within the flow as they pass through the viewing section **120**. The width and depth of the viewing section **120** are thus dictated in large measure by the physical and optical properties of the camera or other imaging equipment employed. Current technology supports a dwell time in the viewing section **120** of on the order of one to five (1-5) seconds. As indicated, the dwell time can be manipulated by adjusting the flow rate of the system for example. Using an approximately twenty-four frames-per-second (~24 fps) digital video imager **170**, this will potentially generate approximately twenty-four to one-hundred twenty (24-120) data frames. Therefore, those skilled in the art will appreciate that the entire system and approach is scalable by using various or even multiple lenses to acquire the desired visual data across the viewing section **120**. As the flow leaves the viewing section **120**, a post-viewing section region, or acceleration or outlet chute **182**, is configured as a contraction within the flow path to accelerate or speed up the flow back to the system velocity after the viewing section **120**. Once again, it will be appreciated by those skilled in the art that a variety of other such components and configurations are possible beyond those shown and described without departing from the spirit and scope of the invention.

[0056] It is further noted in connection with Fig. 2 that in the exemplary embodiment the overall size of the microorganism evaluation system **20** is on the order of 3 ft x 2 ft x 1.5 ft, clearly a portable size, such that the system **20** may advantageously be employed on ships and in other field uses. A relatively small package is also conducive to real time continuously monitoring applications in that the system **20** can be installed in relatively tight packaging constraints. Portability and simplicity of design are further accomplished by the use of gravitational, fluid dynamics effects as a means of flowing or circulating the sample fluid through the system **20** from the sample location to the exit point. In turn, such geometrical

aspects of the design along with the conduit sizes create conditions whereby a determinant of system velocity is the height between the sampling location and the fluid exhaust point of the system, more about which is said below. However, again, there also may be some form of pump augmentation to facilitate system function, as required. It will be appreciated by those skilled in the art that other sizes and packages and related configurations of the system **20** are possible without departing from the spirit and scope of the invention, such that the above discussion is to be understood as merely illustrative.

[0057] With continued reference to Figs. 1 and 2, image capture and processing hardware/software **210** is connected to the imager **170** through a relatively high bandwidth connection, or a connection sufficient for the data acquisition capability of the digital imager **170** employed; software on the image capture and processing device **210** operates to facilitate such image acquisition and manipulation. The data thus captured is then acted on by kinematics analysis software **212**, whether residing on or within the same hardware as the image capture and processing device **210** or a different hardware or computing device. Such software **212** is configured to identify each microorganism as imaged by the viewing section **120** and essentially plot that organism's movement in a frame-by-frame or like fashion so as to thus determine relative angular (directional) or rotational motion or physiological change indicative of life, more about which is said below in connection with Figs. 15 and 16. For example, the kinematics analysis software **212** might look at derivatives such as rate of change in path or rotation as indicative of self-induced motion by the organism and/or rate of change in aspect ratio alone or relative to the path (angular motion) or the organism's orientation (rotational motion) as indicative of self-induced body movement of the organism. It is contemplated that since again the standard velocity profile of the fluid flow in the system **20** will generate different velocities between organisms traveling at the center of a pipe and those that are traveling near the walls of the pipe, both the viewing section **120** and the motion detection software **212** are to be configured to account for such.

[0058] Turning now to Figure 5, there is shown a partial perspective view of an exemplary microorganism evaluation system **20** according to aspects of the present invention substantially consistent with the block diagram representation of Fig. 1 and the schematics of Figs. 2-4. As a threshold matter, it is to be understood that the illustrated hardware components – here essentially the microorganism stimulation section **80**, the flow normalizing section **100**, and the viewing section **120**, as well as the outlet chute **182** leading away from the viewing section **120** – are merely representative or illustrative of aspects of the invention and are not limiting. In such views, it is noted that the pre-conditioning section **30** and other tubing, flow controls and the like are not shown for simplicity. Furthermore, the illuminator **150**, the optical system **160**, and the imager **170** are also not shown, though at least the illumination ports **148** – four in the exemplary embodiment are shown wherein LEDs or the like may be installed so as to illuminate the interior cavity **126** of the viewing section **120**, and the viewing port **144**, specifically – are shown as being integral with the viewing section body **122**. Regarding the optical system **160** and the imager **170**, as explained above, these may be separate or integral components and "off the shelf" or proprietary, but in the exemplary embodiment a camera (not shown) is contemplated wherein the lens would mount or be removably installed directly to or on the optical system mount **130** of the viewing section body **122** such that the lens "looks" substantially straight into the cavity first opening **128** shown as intersecting the optical system mount **130** and, as best seen in the cross-sectional view of Fig. 14, communicating with the body cavity **126**. Again, numerous other hardware components and configurations (geometry, means of assembly, etc.) are possible without departing from the spirit and scope of the present invention.

[0059] With continued reference to Fig. 5, the microorganism stimulation section **80** is shown in the exemplary hardware embodiment as comprising a disorientation spiral **82** or helical tubular member. The disorientation spiral **82** is itself comprised of two turns – a first loop **84** and a second loop **88**, each substantially comprising one revolution or a twist of three hundred sixty degrees (360°), though once again those skilled in the art will appreciate that any number and configurations of loops are possible within the scope of the invention, so long as sufficient

rotation, twisting, or tumbling of the flow is provided so as to stimulate or excite the inertial sensing mechanisms of any living microorganisms within the sample flowing through the stimulation section **80**. The first loop **84** is shown as having a proximal first loop coupling **86**, which is configured for fluid connection to tubing **76** upstream of the stimulation section **80** through which the sample is delivered from the pre-conditioning section **30** (Figs. 1 and 2). As best seen in Figure 8, the first loop coupling **86** may be formed having an internally threaded bore **87** for threadably engaging an external thread on a mating coupling (not shown) formed on the end of the tubing **76**, though it will be appreciated once more than any such coupling or removable engagement means now known or later developed may be employed. Similarly, the second loop **84** is formed having a distal second loop coupling **90** configured for fluid connection to the flow normalizing section **100** and specifically to an inlet chute first coupling **106**. Here, as shown in Fig. 8, the second loop coupling **90** is formed as a conical fitting **91** configured to engage a conical bore **107** (Fig. 9) formed within the inlet chute first coupling **106** so as to open outwardly. As can also be seen in Fig. 8, there is formed axially or lengthwise along the entire disorientation spiral **82** a spiral inner bore **92** through which the sample flows. In the exemplary embodiment, the wall thickness of the disorientation spiral **82** (the first and second loops **84**, **88**) is approximately 3 mm and the inside diameter of the spiral bore **92** is approximately 1.2 mm, more about which will be said below in connection with the sizes of the other components of the exemplary system **20** and the operation thereof.

[0060] Referring again to Fig. 5 and with further reference to the exploded perspective views of Figures 6 and 7, next in sequence is once again the flow normalizing section **100** that itself generally comprises the inlet chute **102**. It is noted that while a section of tubing **94** is shown in Fig. 2 as interconnecting the stimulation section **80** and the flow normalizing section **100**, in the embodiment shown in Figs. 5 and following, the system **20** instead has the disorientation spiral **82** connected directly to the inlet chute **102** – it will be appreciated that any such connectivity of the respective parts of the system **20** is possible in the present invention without departing from its spirit and scope. The chute **102** again has at its proximal end the inlet chute first coupling **106** configured to connect to the spiral second loop coupling **90** and further has at is distal end

an inlet chute second coupling **106** configured for connecting the inlet chute **102** to the viewing section body **122**. Once more, though a particular form and geometry of the inlet chute second coupling **106** is shown, here in the form of plate substantially perpendicular to the axis **116** of the inlet chute **102** and having holes formed for the assembly thereof as by bolts or screws to the respective parts of the viewing section **120**, the invention is not so limited. More notably, and now with further reference to the cross-sectional views shown in Figures 9 and 10, it can be seen that the exemplary inlet chute **102** has an inlet chute body **104** in which is formed an inlet chute inner bore **110** along its entire length. Taking first Fig. 9, a section taken through a substantially horizontal or inlet chute first plane **112**, it can be seen that the bore **110** significantly tapers outwardly or expands from the entrance to the inlet chute **102** at the end adjacent the inlet chute first coupling **106** to the exit from the inlet chute **102** adjacent the inlet chute second coupling **108**. In the exemplary embodiment, the proximal end of the inlet chute inner bore **110** immediately distal or downstream of the conical bore **107** defines an inlet chute first inside diameter that is substantially equivalent to the spiral inner bore **92** for a smooth transition therebetween. This substantially annular inner surface of the fluid flow path then gradually expands going down the inlet chute inner bore **110** to, in the exemplary embodiment, a final width of approximately 20 mm substantially corresponding to the width of the viewing port **144** within the viewing section **120**, resulting in an expansion in this plane of about eight times (8x). Furthermore, referring to Fig. 10, a section taken through a substantially vertical or inlet chute second plane **114**, or a plane substantially perpendicular to that along which the part is sectioned as shown in Fig. 9, the intersection of the inlet chute first and second planes **112**, **114**, in fact, being along or defining the inlet chute central axis **116**, reveals that in this direction the inlet chute inner bore **110** is of a more uniform dimension. More particularly, at the entrance to the inlet chute **102** adjacent the inlet chute first coupling **106**, the dimension across the bore **110** is again approximately 1.2 mm in the exemplary embodiment, which in this second plane **114** then actually tapers down slightly to approximately 1 mm to correspond to the depth of field **D** through the viewing section **120**, more about which is said below. As such, the cross-sectional area of the flow path or inner bore **110** through the inlet chute **102** is approximately 1.1 mm^2 at its entrance ($\pi d^2/4 = \pi(1.2\ mm)^2/4$) while at its exit it is approximately 20 mm^2 (20 mm x 1

mm). It follows that there is a volumetric expansion along the inlet chute inner bore **110** of about twenty times (20x), and it will be appreciated, then, that as the sample flow passes from the disorientation spiral **82** into and through the inlet chute **102** it will have a tendency to normalize and slow down or decelerate as the flow path expands, resulting in relatively more laminar flow prior to the sample then leaving the inlet chute **102** or flow normalizing section **100** and entering the viewing section **120**, a full appreciation of the benefit of which will be gained from the below discussion concerning the microorganism evaluation system **20** in use, and particularly Figs. 16 and 17.

[0061] Briefly turning to Figures 11 and 12, there are shown cross-sectional views of the outlet chute **182** analogous to the views of Figs. 9 and 10 regarding the inlet chute **102**, the outlet chute **182** effectively taking the sample flow away from the viewing section **100** (Figs. 5-7) in much the same way, but in reverse, as the inlet chute **102** delivers the sample flow to the viewing section **120**. Specifically, referring first Fig. 11 showing a section taken in or through a substantially horizontal or outlet chute first plane **192**, it can be seen that the outlet chute inner bore **190** significantly tapers inwardly or contracts from the entrance to the outlet chute **182** at the end adjacent the outlet chute first coupling **186** that is connected to the viewing section body **122** to the exit from the outlet chute **182** adjacent the outlet chute second coupling **188** that is configured to connect to the tubing **196** (Fig. 2) leading eventually back out of the system **20**. Whereas, as shown in Fig. 12, a section taken through a substantially vertical or inlet chute second plane **194**, or a plane substantially perpendicular to that along which the part is sectioned as shown in Fig. 11, the intersection of the outlet chute first and second planes **192**, **194**, once again being along or defining the outlet chute central axis **195**, reveals that in this direction the outlet chute inner bore **190** is of a more uniform dimension, here slightly expanding as the flow heads away from the viewing section **120** through the outlet chute **182**. Once again, in reverse of the inlet chute **102**, here with the outlet chute **182** there is an overall contraction or reduction in size of the inner bore **190** along its length in the direction of flow, which those skilled in the art will appreciate will have a tendency to gradually speed up again or accelerate the flow as it leaves the microorganism evaluation system **20**. In the exemplary embodiment the inlet chute

102 is about twice as long as the outlet chute **182**, or six inches (6 in) compared to three inches (3 in), respectively, though once more it will be appreciated that all such sizes and geometries are merely illustrative of features and aspects of the present invention and non-limiting.

[0062] Referring again to Figs. 5-7 and now with reference to Figs. 13 and 14 as well, downstream of the flow normalizing section **100**, or between the inlet and outlet chutes **102**, **182**, is again of course the viewing section **120**. In the partial exploded view of Fig. 13, which is effectively the viewing section body **122** upside down with the back plate **138** not shown for clarity, it can be seen that in the exemplary embodiment the body **122** effectively has a viewing section body inlet **124** coinciding with the distal end of the inlet chute **102** at its second coupling **108** and a viewing section body outlet **146** coinciding with the proximal end of the outlet chute **182** at its first coupling **186**, which inlet **124** and outlet **146** are each in fluid communication with the hollow interior of the viewing section **120**, or the viewing section body cavity **126**. In Fig. 14 there is shown a partial cross-sectional view of the viewing section **120**, here with the viewing plate **136** not shown for clarity. As best appreciated from Figs. 6 and 14, three sides of the actual viewing port **144** or the true flow path through the viewing section body cavity **126** are formed by a channel **140** formed in the back plate **138** that installs over the relatively larger cavity second opening **132** substantially opposite the cavity first opening **128** adjacent the viewing section optical system **160** as described above to substantially enclose the cavity **126**, the back plate channel **140** having a channel bottom **141** and substantially perpendicular channel side walls **142**. Opposite and substantially parallel to the channel bottom **141** there is positioned a clear or substantially transparent viewing plate **136** offset from the cavity first opening **128**, the viewing plate **136** seating on opposite cavity shelves **134** formed in the viewing section body **122** so as to open into the cavity **126** and thus forming the fourth side of the viewing port **144**. In the exemplary embodiment, the viewing plate **136** also seats on the tops of the channel side walls **142**, or is pinched between the channel side walls **142** and the cavity shelves **134**, such that it will be appreciated that the depth of the channel **140**, or the height of the channel walls **142** effectively defines the height of the flow path through the viewing section **120** or the depth of field **D** for the optical system **160** that is “looking at” the sample flow through the cavity first

opening **128**, a portion of the open cavity **126**, and the viewing plate **136** beneath which the flow is passing. It will be further appreciated that the dimensions of the viewing plate **136** substantially set the "footprint" size of the viewing port **144**, which in the exemplary embodiment is 11.25mm long by 20mm wide, setting then a viewing port volume (L x W x H) of approximately 225 mm^3 (11.25 mm x 20 mm x 1 mm). Again, this general geometry is discussed further below in terms of throughput and operation of the overall system **20**, particularly in the context of Figs. 16 and 17. With continued reference to Figs. 5-7, 13 and 14, there is also shown multiple illumination ports **148** intersecting the viewing section body **122**, in each of which there may be installed LEDs or the like so as to illuminate the interior cavity **126** of the viewing section **120**, and the viewing port **144**, specifically. Again, any number and configuration of such illumination ports **148** and any lighting units now known or later developed may be incorporated into the viewing section **120** without departing from the spirit and scope of the present invention.

[0063] Referring next to Figure 15, there is shown a flow chart depicting the basic operation or use of a microorganism evaluation system **20** according to aspects of the present invention. In use of such an exemplary system **20** as shown in Figs. 1-14, the first step **220** is to acquire the sample to be tested, which is beyond the scope of the present invention, though per the embodiment shown in Figs. 1 and 2, there is one exemplary embodiment effectively a tank system identified here as the sample pre-conditioning section **30** made up of one or more tanks, here an external sample tank **32** and a main sample tank **52** (Figs. 1 and 2), that together hold a finite volume of fluid sample for evaluation within or by the system **20**. It will be appreciated that in other contexts different types and numbers of tanks may be employed, or a more continuous system may be employed wherein the fluid sample is acquired on a more real-time basis from a larger body or flow of water or other fluid. Once a sample is acquired, in step **222** the sample may be pre-conditioned, which stands for the general proposition of removing from the fluid sample inorganic or dead organic matter as by settling, filtration, or other appropriate techniques now known or later developed, so that what is primarily left in the water sample is organic material that may or may not be living, which determination is the primary purpose of

the present invention. At step **224** the fluid sample is flowed to the microorganism stimulation section **80** (Figs. 1 and 2), and at step **226** any microorganisms therein are stimulated, which again may be inertial stimulation as per the disorientation loop **82** shown in Figs. 2 and 5, may be hydraulic or mechanical stimulation as shown and described below in connection with the alternative exemplary embodiments of Figures 18 and 19, or may be any other such stimulation device or method now known or later developed, any such device or method again stimulating or exciting the senses of the microorganisms, as compared with chemical staining or response and other such techniques known and employed in the art in determining organism life or viability, though in certain contexts such evaluation techniques (motive and chemical) may be used in tandem. At step **228**, the flow is normalized as by flowing through the exemplary flow normalizing section **100** (Figs. 1 and 2), and then at step **230** the sample passes into the viewing section **120** (Figs. 1 and 2). At step **232** the sample within the viewing section **120** may be illuminated as by the illuminator **150** (Figs. 1 and 2), and then the optical system **160** (Figs. 1 and 2) in conjunction with the imager **170** (Figs. 1 and 2) may obtain visual images of the sample at step **234**. Finally, in terms of the general process or method of using the system **20**, at step **236**, the visual image data is analyzed to determine whether any of the microorganisms within the sample are living.

[0064] In connection with this last step **236** (Fig. 15) and the analysis of the microorganisms of which image data is captured in the viewing section **120** after being excited in the stimulation section **80**, referring now to Figures 16A-16C, there are shown schematics of essentially three different motive responses of a microorganism **M** that may be induced and thus be observed within the viewing section **120**. The theory again is that the helix geometry of the disorientation spiral **82** (Figs. 2 and 5) will induce the fluid in the tube to rotate around the tubular axis, which will stimulate (agitate) the inertial sensing mechanisms found within the microorganisms. A finite amount of time after the stimulation event has ended the living microorganisms will react with self-generated motion as their inertial measurement system stabilizes while they are floating in the “calm waters” of the viewing section **120**. For example, they may attempt to straighten themselves out after they sensed being tumbled around. Another way of describing

the thinking embodied in this aspect of the invention is that the microorganisms will react to "feeling dizzy." Accordingly, the microorganism stimulation section **80** shown in Figs. 2 and 5 supports momentary stimulation of a live organism's inertial sensory perception. The amplitude and duration of stimulation necessary to induce such a response as self-generated motion, as by a "tumbling" microorganism attempting to "right" itself, can be characterized by both a frequency spectrum and a rotational time history. The frequency spectrum is particularly characterized by amplitude and frequency of the stimulation and can be expressed as power spectral density ("PSD"), whereas the rotational time history is particularly characterized by the rate and duration of the organism's motive response to the stimulation and can be expressed as energy spectral density ("ESD"), or the energy of the disorientation event. Certain microorganisms will be particularly sensitive to certain frequencies and amplitudes ("PSD"), which will be excited by an appropriate geometry of the spiral loop agitator or other such stimulus ("ESD"), as described above in connection with other aspects of the exemplary system of Figs. 1-14 as well as in connection with the alternative embodiments shown particularly in Figs. 18 and 19. Thus, the geometry or other properties of the helix are determined by the PSD, ESD, and acceleration profiles that are required to properly stimulate the microorganism **M**. In a bit more detail, again, the PSD describes both the frequency and amplitude of the stimulation event. Whereas, the ESD describes the time-history of the rotation profile of the stimulation event, such that the integral of this time-history, or "area under the curve," is the energy induced on the microorganism **M** during the stimulation event. Accordingly, the rotation profile depicts the "slopes" of the event, which is the rate of change of the rotational forces induced on the microorganism **M**. With a certain acceleration or rate-of-change in rotation being desirable, it being observed that microorganisms will adapt to relatively gentle motions and not necessarily generate counter-acting self-induced motion, while adequately rapid changes in the local hydrodynamic environment, or in acceleration or motion more generally, will tend to cause self-induced motion by the microorganism **M**. The optimal amount of stimulation required is bounded in both amplitude and duration, in that both parameters requiring a minimum threshold to be exceeded, and a maximum to not be attained. It will thus be appreciated once more that various geometries and features of the microorganism stimulation section **80** are possible

beyond the double-loop spiral agitator **82** depicted in Figs. 2 and 5, again depending on the type of organism that is to be evaluated, fluid type and flow characteristics, and other such contextual factors. Generally speaking, vertical orientations of the stimulation section **80** are preferred due the decoupling from localized pitching or roll motion (as on a boat for example), and the tendency of Zooplankton to generate a more vertical motion that supports a typical feeding pattern. Once more, then, those skilled in the art will appreciate that the invention is not limited to the particular stimulation section shown and described in connection with Figs. 2 and 5, but may instead take a number of other forms to suit a particular context without departing from the spirit and scope of the invention. For example, in alternative embodiments, direct hydraulic excitation or indirect hydraulic (mechanical) excitation may be employed instead, such as by transverse water flows or vibration induction, as represented schematically in Figs. 18 and 19. Any such approach would again employ a power spectral density ("PSD") generator to quantify the stimulation (amplitude and frequency of vibration or intensity/pressure and frequency of water pulses), more about which is said below. In connection with the "two loop" disorientation spiral **82** shown in Figs. 2 and 5, such will tend to "saturate" the inertial sensing mechanism ("ISM") of the microorganism **M** so as to yield relatively more consistent results when the organism **M** is "released" from the spiral **82**. In the exemplary embodiment, the geometry of the disorientation spiral **82** and the contemplated flows therethrough produce a rotational inertial stimulus of approximately six radians per second (6 rad/sec). After the flow normalization section **100** and entry of the sample into the viewing section **120** having in the exemplary embodiment a relatively high width-to-height aspect ratio, on the order of twenty to one (20:1), with the viewing chamber volume (L x W x H) again being 11.25 mm x 20 mm x 1 mm, it has been determined, for example, that utilizing current video camera technology with a nominal output resolution of 2.1 megapixels can resolve down to about ten (10) microns and will still allow for one to five second (1-5 sec) dwell times within the viewing port **144** and the acquisition of twenty (20) or more discrete frames per organism **M** – a sufficient and even substantial data set from which to make determinations regarding relative movement and hence organism life.

[0065] Referring first to Fig. 16A, then, there is shown schematically a microorganism **M** changing its direction incrementally by an angle **α** from the initial flow velocity vector **v**, indicating that it is living in deviating from the course or direction along which a non-living organism would be carried. This is one example of a motive response from a microorganism **M** that is essentially "swimming" in the "calm waters" of the viewing section **80** after having its ISM was saturated in the spiral stimulation section **80**. As shown in Fig. 16B, another exemplary motive response is an organism **M** spinning as it travels along the normal flow velocity vector **v**, which again is not motion that would be induced by the laminar substantially straight-line flows through the viewing section **120**, but would be indicative of self-generated motion by a living organism. And finally, as shown in Fig. 16C, yet another exemplary motive response that may be observed in a microorganism **M** that has been stimulated is a change in aspect-ratio, which essentially entails an organism twisting or wriggling or otherwise flexing or moving its body, any of which would again be self-generated and not a result of the sample flow, particularly within the viewing section **120**. It will be appreciated that while discrete organism responses are shown in Figs. 16A, 16B, and 16C, multiple such responses may be present in a single organism at the same time, such as an organism deviating from the normal flow velocity path and simultaneously rotating or spinning (combination of Figs. 16A and 16B) or an organism maintaining the same flow velocity path but also wriggling and curling while rotating (combination of Figs. 16B and 16C). Any combinations of such motive responses and others are possible, and the detection of one or more such movements as an organism passes through the viewing section **120** would be sufficient to indicate life.

[0066] In terms of the organism image data aggregation and analysis – the detection and interpretation of microorganism motive response – attention is now directed to Figures 17A and 17B depicting the stimulation energy supplied to an organism and that organism's measured response, respectively. By way of further background, this portion of the discussion relating effectively both to the capabilities of the optical system **160** and imager **170** as well as the image capture and processing hardware/software **210** and the kinematics analysis algorithm **212**, in addition of course to the geometry of the components and flow rates therethrough as described above, under certain conditions "artifacts" will be created by the digital imager **170**, which will

or could make quantitative interpretation incorrect. That is, there will be a certain level of inaccuracy in the amount of frame-to-frame apparent "motion" observed, depending on a number of factors. In a practical sense, when applying a derivative function it will tend to amplify any inaccuracies in spatial content, and therefore make more strict quantitate analysis problematic. However, there is relative robustness with the current approach regarding the identification of deviation from normal, not "how far" from normal; a qualitative analysis of the data – as in "Did the microorganism **M** move from the normalized path **v**?" – is an adequate determination in this context. Put another way, it is not necessary to know "how much" the microorganism **M** moved to know whether or not it is alive; detection of some movement (linear or rotational or of the aspect ratio, for example) from the normalized path or a starting orientation or body shape will qualitatively determine organism life, while still leaving open the option for quantitative assessment, including based on technological advances so as to reduce or eliminate the "artifacts" in the image data that could skew quantitative results. Technology in terms of optics (resolution) and processing (data transfer and compiling) is continuing to improve, so the artifacts that are generated will become less significant over time. And a very small percentage of the pixels will be changing from frame to frame in the present application, which will significantly reduce the amount of artifacts generated already. To further assist, the relatively small depth of field **D** (Fig. 4), in the exemplary embodiment on the order of one millimeter (1 mm), enables opening up the camera aperture and letting in more light for the image sensor **160**, running greater practical shutter speed values, and producing greater clarity in the images captured.

[0067] Back to Fig. 17A, then, there is shown a graph depicting a representative inertial stimulation **i** (vertical axis) over time **t** (horizontal axis) to which the microorganism **M** is subjected. As can be seen, for a certain duration there is a definite inertial event, such as corresponding to the time the organism spends in the stimulation section **80**, or the disorientation spiral **82**, specifically, which energy then dampens out over time following discharge from the stimulation section **80**, essentially corresponding to the time the organism spends in the flow normalizing section **100** and then the viewing section **120** where the flow rate

of the fluid sample is slowest (the organism would have the longest "dwell time" in the "calm waters" of the viewing section). Then with reference to Fig. 17B, there is shown a similar graph now plotting a representative motive response **r** (vertical axis) over time **t** (horizontal axis), with the vertical axes of Figs. 17A and 17B aligned so as to easily see the motive response **r**, as expected, time-wise lagging the inertial stimulation **i**. Moreover, the response **r** is plotted below the horizontal axis, or "negative," simply to indicate that the response **r** is in reaction to and "equal and opposite" or "proportional" to the inertial stimulation **i**. Notably, once again, it can be seen via a comparison of Figs. 17A and 17B that it is not until after the inertial stimulation event has ended and the inertial stimulation **i** has begun to dampen out that the organism response **r** then sharply picks up, which period of active response again, based on the geometry and flow rates within the system **20**, is to coincide with the time the organism is passing through the viewing section **120**, which in the exemplary embodiment is to be approximately on the order of one to five (1-5) seconds. Those skilled in the art will appreciate that the graphs shown in Figs. 17A and 17B, though based on actual observations, are not based on empirical data or the plotting of data points, and so in some sense are theoretical and so are not to be taken strictly or literally, hence there being no values or graduations on the graph axes. Accordingly, it will also be appreciated that various other scenarios of the inertial stimulation **i** and the motive response **r** are possible within the present invention without departing from its spirit and scope.

[0068] Turning now to Figure 18, there is shown a schematic view of an alternative exemplary embodiment of a microorganism evaluation system **20** according to aspects of the present invention. Here, it is indicated that a hydraulic and/or mechanical excitation device **96** may be employed in or adjacent the flow some distance upstream of the viewing section **120**, which agitator would again be coupled to a PSD generator **98**. Generally, forces are hydraulically coupled to the organisms in the sample due to the fact that they are suspended in fluid. In direct hydraulic excitation or stimulation, a series of small tubes (not shown) intersecting the flow path may be employed to agitate the organisms as they pass through this excitation section **80**, such as by a steady cross-flow or bursts or pulses of fluid transverse to the primary axis of fluid flow. Any such disruption, causing turbulence and tending to disorient the organisms, would thereby

induce self-generated motion by living organisms in response, as discussed above. The concept of a reaction delay or an "agitation response decay time" wherein motion of the organisms is given time to commence but not too much time so as to commence and then cease before the viewing section **120**, while still providing sufficient length in a normalizing section **100** or the like for the flow to normalize, as discussed above particularly in connection with Fig. 2, would again be applicable here in the context of hydraulic and/or mechanical excitation. With mechanical (indirect hydraulic) excitation, as in the system schematic of Figure 19, the stimulus mechanism is effectively mechanical to hydraulic to inertial, such that this approach would be relatively less direct, as it is believed that ultimately the organisms respond to inertial stimuli. Either approach would again employ a power spectral density ("PSD") generator **96** to quantify the stimulation (amplitude and frequency of vibration in the context of mechanical excitation or intensity/pressure and/or frequency of water pulses in hydraulic excitation), and though the mechanical approach is shown in conjunction with stimulation at or contemporaneous with the viewing section **120** and the hydraulic approach upstream of the viewing section **120**, other such variations are possible. Once more, it will be appreciated by those skilled in the art that while various embodiments and related operation have thus been shown and described, and particularly various means of exciting, agitating, or otherwise stimulating microorganisms, the invention is not so limited, but may instead involve any means now known or later developed for imparting at least inertial stimulation to organisms within a fluid flow for the purpose of determining whether any are living based on detected responsive movement and/or motion. Moreover, in some embodiments inertial stimulation may not even be employed, instead relying on some other agitator such as relative velocity, relative pressure, or light to stimulate the organisms in the test sample. Accordingly, it is to be expressly understood that features or aspects of the present invention as disclosed herein may be combined in various ways to achieve further alternate microorganism evaluation systems without departing from the spirit and scope of the invention.

[0069] Finally, in Figure 20, there is shown an alternative dual microorganism evaluation system **20** having a first or primary, relatively larger microorganism stimulation section **80'** that

is otherwise quite analogous to that of the system **20** of Figs. 1-14, which stimulation section **80'** is itself sampled by a secondary microorganism stimulation section **80** that is in most respects the same as that of the first exemplary embodiment of Figs. 1-14, such sampling being as by isokinetic sample, for example. For illustration, the larger disorientation spiral **82'** may have an inside diameter of approximately 13 mm feeding into a viewing section **120'** that is nominally 100 mm wide by 6 mm high, as compared to that of the first exemplary embodiment wherein the secondary spiral **82** in the dual system **20** of Fig. 20 has a nominal inside diameter of 1.2 mm and a viewing section **120** that is nominally 20 mm wide by 1 mm high. The resulting dual system **20** enables more throughput for use in contexts where larger volumetric or real-time sampling is desired as well as potentially enabling higher accuracy by secondary line sampling and evaluation within a viewing section **120** that has a nominal 1 mm depth of field while still allowing an acceptable aggregate throughput by employing the primary line having a nominal 6 mm depth of field, or a cross-sectional area of 600 mm^2 versus the 20 mm^2 of the secondary line that is more analogous to the exemplary embodiment system **20** according to aspects of the present invention. It will once again be appreciated that such features may be combined in a variety of ways and employ a variety of technologies now known or later developed without departing from the spirit and scope of the invention.

[0070] To summarize, regarding the exemplary embodiments of the present invention as shown and described herein, it will be appreciated that a microorganism evaluation system is disclosed and configured for imparting at least inertial stimulation to organisms within a fluid flow for the purpose of determining based on detected responsive movement and/or motion of the organisms whether any are living. Because the principles of the invention may be practiced in a number of configurations beyond those shown and described, it is to be understood that the invention is not in any way limited by the exemplary embodiments, but is generally directed to a microorganism evaluation system for analyzing microorganisms within a fluid flow, comprising a microorganism stimulation section and a viewing section in fluid communication therewith and having an optical system mounted relative to the viewing section body for viewing the fluid flow within the viewing port thereof, whereby image data relating to the fluid flow and any

microorganisms therein is acquired via the optical system for analysis, and so is able to take numerous forms to do so without departing from the spirit and scope of the invention. It will also be appreciated by those skilled in the art that the present invention is not limited to the particular geometries and materials of construction disclosed, but may instead entail other functionally comparable structures or materials, now known or later developed, without departing from the spirit and scope of the invention. Furthermore, the various features of each of the above-described embodiments may be combined in any logical manner and are intended to be included within the scope of the present invention.

[0071] While aspects of the invention have been described with reference to at least one exemplary embodiment, it is to be clearly understood by those skilled in the art that the invention is not limited thereto. Rather, the scope of the invention is to be interpreted only in conjunction with the appended claims and it is made clear, here, that the inventor(s) believe that the claimed subject matter is the invention.

CLAIMS

What is claimed is:

1. A microorganism evaluation system for analyzing microorganisms within a fluid flow, comprising:

a microorganism stimulation section comprising a disorientation spiral having a spiral inner bore defining a first cross-sectional area and thereby allowing for a first flow rate therethrough of the fluid flow, the disorientation spiral configured for inducing a motive response in a living microorganism within the fluid flow passing therethrough; and

a viewing section in fluid communication with the microorganism stimulation section, the viewing section comprising a body having formed therein a body cavity defining a viewing port visible through a cavity first opening formed in the body so as to be in communication with the body cavity, a viewing section body inlet and an opposite viewing section body outlet both being further formed in the body so as to be in communication with the body cavity and provide an unobstructed flow path therebetween through the viewing port, the viewing section further comprising an optical system mounted relative to the body for viewing the fluid flow within the viewing port through the cavity first opening, the optical system being a camera-like device capable of acquiring image data; further wherein:

the viewing section is configured in cooperation with the optical system such that multiple frames of image data relating to the fluid flow and a discrete microorganism therein are acquired via the optical system for analysis, movement of a microorganism relative to the fluid flow in response to flow through the disorientation spiral as per the acquired image data being indicative of microorganism viability; and wherein:

the viewing port of the viewing section defines a second cross-sectional area, the second cross-sectional area being greater than the first cross-sectional area and thereby causing a second flow rate therethrough of the fluid flow to be less than the first flow rate, whereby the fluid flow

through the viewing port is rendered relatively slow and laminar, thereby contributing to acquisition of the multiple frames of image data.

2. The system of claim 1 further comprising a hydraulic/mechanical excitation device.

3. The system of claim 2 wherein the hydraulic/mechanical excitation device is upstream of the viewing section.

4. The system of claim 2 wherein the hydraulic/mechanical excitation device is co-located with the viewing section.

5. The system of claim 1 further comprising a flow normalizing section in fluid communication between the microorganism stimulation section and the viewing section, the flow normalizing section comprising an inlet chute having a tapered inlet chute inner bore.

6. The system of claim 5 wherein:

the inlet chute is formed with an inlet chute first coupling configured for connecting to the microorganism stimulation section, the inlet chute inner bore also defining at the inlet chute first coupling the first cross-sectional area of the spiral inner bore of the disorientation spiral and thereby allowing for the first flow rate therethrough of the fluid flow; and

the inlet chute is further formed with an inlet chute second coupling configured for connecting to the viewing section and also defining at the inlet chute second coupling the second cross-sectional area of the viewing port and thereby allowing for the second flow rate therethrough of the fluid flow, whereby the inlet chute of the flow normalizing section receives the fluid flow at the first flow rate as delivered by the disorientation spiral of the microorganism

stimulation section and delivers the fluid flow at the second flow rate to the viewing port of the viewing section.

7. The system of claim 5 wherein:

the inlet chute is formed in an inlet chute first plane and a perpendicular inlet chute second plane, the inlet chute first and second planes intersecting along an inlet chute central axis; and

the inlet chute inner bore is tapered in the inlet chute first plane greater than in the inlet chute second plane, whereby the inlet chute inner bore in the inlet chute second plane is substantially equivalent to the spiral inner bore.

8. The system of claim 7 wherein the viewing port of the viewing section defines a depth of field in the axis of the cavity first opening that is substantially equivalent to both the spiral inner bore and to the inlet chute inner bore in the inlet chute second plane.

9. The system of claim 1 wherein the viewing section further comprises an illuminator.

10. The system of claim 9 wherein:

the body is formed having at least one illumination port substantially communicating with the body cavity, the at least one illumination port being offset from the cavity first opening; and

the illuminator comprises an at least one light source positioned within the at least one illumination port.

11. The system of claim 1 further comprising a sample pre-conditioning section upstream of and in fluid communication with the microorganism stimulation section.

12. The system of claim 11 wherein the sample pre-conditioning section comprises:

an external sample tank; and

a main sample tank in fluid communication with the external sample tank and with the microorganism stimulation section.

13. The system of claim 1 wherein a primary microorganism stimulation section and viewing section are configured so as to be sampled by a secondary microorganism stimulation section and viewing section, the primary microorganism stimulation section being at least double the size of the secondary microorganism stimulation section and the primary viewing section being on the order of five times the width and thirty times the cross-sectional area of the secondary viewing section.

14. The system of claim 1 wherein the fluid flow within the viewing port of the viewing section defines a transit time for each microorganism within the fluid flow of at least one second, the transit time being the amount of time each microorganism dwells within the viewing port so as to be visible to the optical system, whereby the transit time contributes to the acquisition of the multiple frames of image data.

15. The system of claim 1 wherein at least ten frames of image data are acquired for each microorganism.

16. A microorganism evaluation system for analyzing microorganisms within a fluid flow, comprising:

a means for inducing a motive response in a living microorganism within the fluid flow;

a flow normalizing section comprising an inlet chute having a tapered inlet chute inner bore; and

a viewing section in fluid communication with and downstream of the flow normalizing section, the viewing section comprising a body having formed therein a body cavity defining a viewing port visible through a cavity first opening formed in the body so as to be in communication with the body cavity, a viewing section body inlet and an opposite viewing section body outlet both being further formed in the body so as to be in communication with the body cavity and provide an unobstructed flow path therebetween through the viewing port, the viewing section further comprising an optical system mounted relative to the body for viewing the fluid flow within the viewing port through the cavity first opening; further wherein:

the viewing section is configured in cooperation with the flow normalizing section and the optical system such that multiple frames of image data relating to the fluid flow and a discrete microorganism therein are acquired via the optical system for analysis, movement of a microorganism in response to the means for inducing as detected in the viewing section being indicative of microorganism viability.

17. The system of claim 16 wherein the means for inducing comprises at least one of a disorientation spiral and a hydraulic/mechanical excitation device co-located with a microorganism stimulation section in fluid communication with and upstream of the flow normalizing section.

18. The system of claim 16 wherein the means for inducing comprises the inlet chute co-located with the flow normalizing section.

19. The system of claim 16 wherein the means for inducing comprises at least one of a light source and a hydraulic/mechanical excitation device co-located with the viewing section.

20. The system of claim 16 wherein:

the inlet chute is formed with an inlet chute first coupling defining a first cross-sectional area of the inlet chute inner bore and thereby allowing for a first flow rate therethrough of the fluid flow; and

the inlet chute is further formed with an inlet chute second coupling configured for connecting to the viewing section and defining a second cross-sectional area of the inlet chute inner bore, the second cross-sectional area being greater than the first cross-sectional area and thereby causing a second flow rate therethrough of the fluid flow to be less than the first flow rate.

21. The system of claim 20 wherein:

the means for inducing further comprises a disorientation spiral having a spiral inner bore further substantially defining the first cross-sectional area; and

the viewing port further substantially defines the second cross-sectional area, whereby the inlet chute of the flow normalizing section receives the fluid flow at the first flow rate as delivered by the disorientation spiral and delivers the fluid flow at the second flow rate to the viewing section.

22. The system of claim 16 wherein:

the inlet chute is formed in an inlet chute first plane and a perpendicular inlet chute second plane, the inlet chute first and second planes intersecting along an inlet chute central axis;

the inlet chute inner bore is tapered in the inlet chute first plane greater than in the inlet chute second plane; and

the viewing port of the viewing section defines a depth of field in the axis of the cavity first opening that is substantially equivalent to the inlet chute inner bore in the inlet chute second plane.

23. A microorganism evaluation system for analyzing microorganisms within a fluid flow, comprising:

a sample pre-conditioning section;

a microorganism stimulation section in fluid communication with the sample pre-conditioning section, the microorganism stimulation section comprising a disorientation spiral for inducing a motive response in a living microorganism within the fluid flow passing through the disorientation spiral;

a flow normalizing section in fluid communication with the microorganism stimulation section, the flow normalizing section comprising an inlet chute having a tapered inlet chute inner bore; and

a viewing section in fluid communication with the flow normalizing section, the viewing section comprising a body having formed therein a body cavity defining a viewing port visible through a cavity first opening formed in the body so as to be in communication with the body cavity, a viewing section body inlet and an opposite viewing section body outlet both being further formed in the body so as to be in communication with the body cavity and provide an unobstructed flow path therebetween through the viewing port, the viewing section further comprising an optical system mounted relative to the body for viewing the fluid flow within the viewing port through the cavity first opening; further wherein:

the viewing section is configured in cooperation with the flow normalizing section and the optical system such that at least ten frames of image data relating to the fluid flow and a discrete microorganism therein are acquired via the optical system for analysis, movement of a microorganism in response to passing through the disorientation spiral as detected in the viewing section being indicative of microorganism viability.